DREDGING
AND
DREDGING APPLIANCES

P. M. DEKKER

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DREDGING AND DREDGING APPLIANCES

DREDGING AND DREDGING APPLIANCES

BY

P. M. DEKKER

WITH AN INTRODUCTION BY

SIR ROBERT HADFIELD

LONDON
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c

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INTRODUCTION TO THE ENGLISH EDITION

After reading Mr. P. M. Dekker's excellent book with much interest, I offer him my hearty congratulations on the result of much laborious study and time devoted to its preparation.

The somewhat inartistic piece of machinery known as the dredger appeals to me in a particular degree, because in it was made the first practical application of the steel I discovered in 1882, known now as manganese steel. My first paper in regard to this material, entitled "Manganese and its Application to Metallurgy," was read before the Institution of Civil Engineers on February 28th, 1888.

It may be of historical interest to recall the circumstances of the first application of this new material which was to play so important a part in the products of metallurgy throughout the world. It happened that while I was carrying out my first experiments, one of Messrs. Cochrane & Fowler's inspectors was at my company's works in Sheffield in regard to certain steel castings we were making for the Dredger Department of the Preston Corporation (Ribble Navigation). He was much interested in some specimens of our then new manganese steel, and invited my firm to make a few sample manganese steel dredger pins on the ground that the unusual combination of hardness and toughness in the steel would render it particularly suitable for the purpose.

When we wrote, after about nine months, to the engineer for a report on these pins we were told they were lost, and it was no use troubling any more about them. However, about three months later, when the dredger itself came into harbour for repair, this set of four manganese steel pins was found practically unworn after fifteen months of service ; the ordinary steel pins were worn out and useless in three or four months. And so a set of manganese steel pins for a complete chain of buckets was then ordered, and since that time many hundreds of thousands of dredger pins and bushes and other wearing parts have been used throughout the world, adding greatly to the efficiency of the dredgers so equipped.

Encouraged by this success, numerous other applications of manganese steel followed, and to-day the world cannot get on without this valuable product for dredger work, tramways, railways, crushing machinery and hosts of other applications. Thus "from small beginnings great things grow."

In regard to Mr. Dekker's book itself, let me say that the methodical and clear manner in which the author has put together his valuable experience of over thirty-five years renders his conclusions of double value to those interested in dredging ; and I am sure that all concerned in harbour work and other applications involving study of the principles of dredging engineering will be grateful to Mr. Dekker for the immense amount of practical information he has provided.

ROBERT HADFIELD.

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PREFACE

THE sole aim of this work is to give an account of the development of dredging appliances in Holland. The idea was suggested because I was often asked to give information about this subject. I think it would be a pity if the history of its development should be lost. This development having taken place during the last half-century, it does not seem quite impossible that this would be the case, so that the next generation will have to accept by tradition what the present one has largely witnessed. I intend to give an account of this development until the present day, and not a detailed technical work.

I will do this to the best of my knowledge, as I have witnessed and watched the development for more than forty years. I want to draw attention to the fact that the machinery mentioned in this work has been chosen arbitrarily, not with the intention to advertise certain firms, everybody connected with this business having contributed to the development of dredging appliances.

I have to thank all those who have helped me with such great kindness in collecting the necessary data, as well as for their permission to publish them.

P. M. DEKKER.

THE HAGUE.

INTRODUCTION

DREDGING APPLIANCES

All machinery which serves to remove soil may be classified under the title "Dredging Appliances," which, again, may be sub-divided under two distinct headings :

(*a*) Machinery applied for the purpose of dredging under water and bringing up the material to the surface ;

(*b*) Machinery necessary for the excavation or removal of soil on dry land.

The first class includes articles such as "bucket dredgers" and "suction dredgers"; the second "elevators" and "excavators."

The Priestman grab dredger may be ranged under both classifications.

A perusal of the various works and periodicals for the purpose of ascertaining the origin of dredging appliances will lead to the discovery that we must seek their origin not only in Holland, but also abroad ; but even with these publications at our disposal it will be found difficult to trace the real line of development.

As regards the "more recent" development, England and Holland may safely claim to have made the greatest progress, each with its own characteristics, resulting from the entirely different nature of the soils of the two countries. In England soils are found that are difficult to dredge ; in Holland, on the contrary, very light kinds are generally found. This is probably the main reason why, from the beginning, English dredgers were of heavier build than Dutch. It was not before the Dutch contractors had acquired much experience abroad that they, too, made their machinery heavier, without, however, abandoning their own types.

Up to the present time the majority of dredging appliances have been built in England and Holland, the latter country fully maintaining its old reputation in this domain. Of late years a number of dredging appliances have been built in Germany.

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UNIVERSITY COLLEGE,
NOTTINGHAM.

DREDGING AND DREDGING APPLIANCES

PART I

BAG AND SPOON

In the *Zeitschrift für Binnen-Schiffahrt*, dated February 1st, 1911, there are to be found some illustrations (Figs. 1, 2, 3) showing that at an early date the want of dredging appliances was badly felt. Amongst these there may be observed a kind of bag with spoon, and we may consider the " bag and spoon " as one of the probable origins of the bucket dredger (Fig. 4).

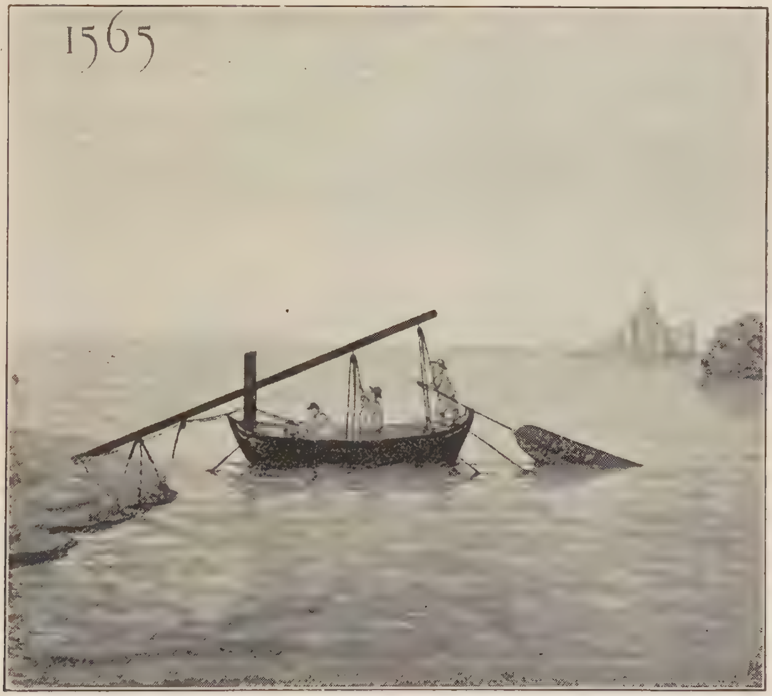


Fig. 1.

It is remarkable that in this case the original design has been so well preserved, for even now it has not been ousted by any of the later appliances. At the present time dredging with the " bag and spoon " is sometimes the only method that can be used in places where there is not sufficient room for a bucket dredger (Fig. 5). In the illustration men are to be seen working in ditches with the bag and spoon, also in little barges on the rivers using it to raise sand. It is not at all easy to bring the

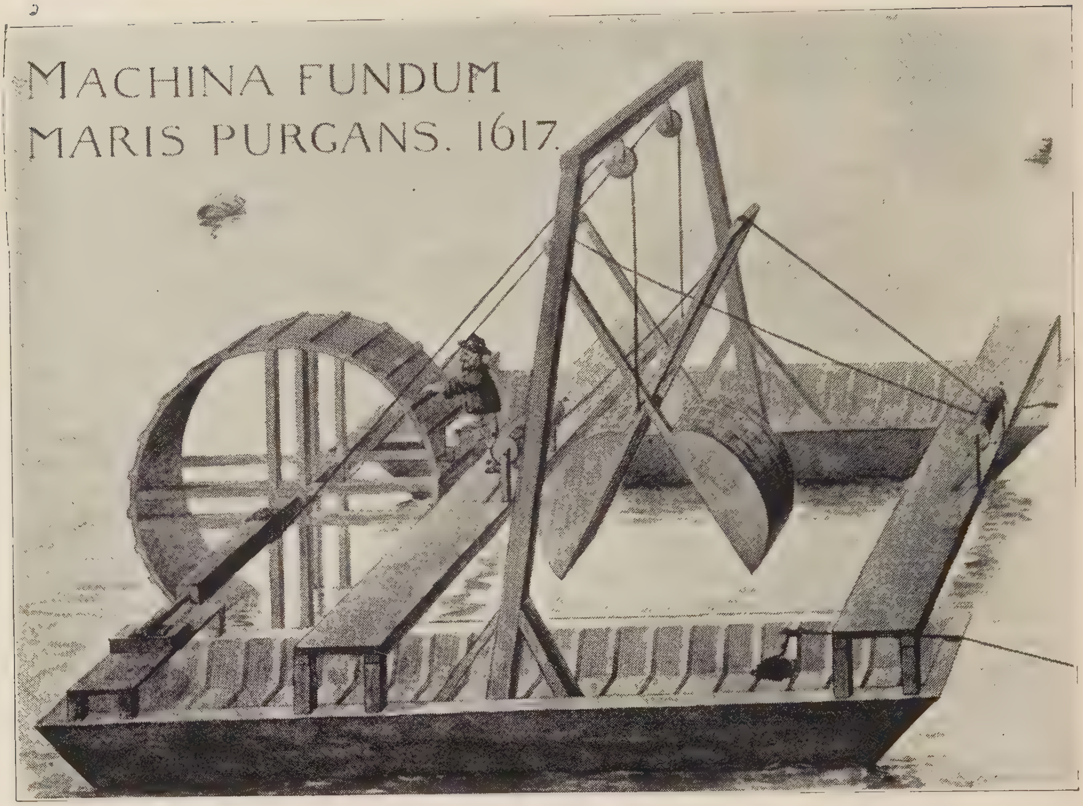


Fig. 2.

linen bag attached to the spoon, well filled to the surface, and we may safely assume that this is an art that has to be learned like any other, if a good day's wage is to be earned (Figs. 6, 7).

The " bag " usually consists of a leather or linen bag of comparatively small capacity, and is attached to a ring and spoon with a pole ; in some cases the linen bag is replaced by a larger iron bucket, raised by means of a winch.

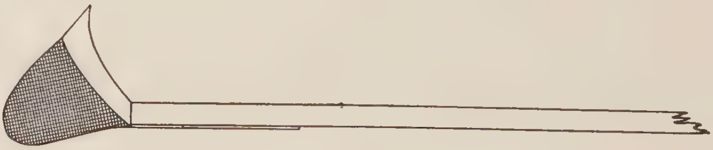


Fig. 3.

From another illustration (Fig. 11) it may be inferred that very early the bottom of the bucket was opened by means of a hinge and catch for the purpose of quickly emptying it of its contents, and in this respect the " bag-and-spoon " dredger may justly be looked upon as the origin of the excavator, more especially of the type known as the " iron man," a type which is largely used abroad (chiefly in North America) to

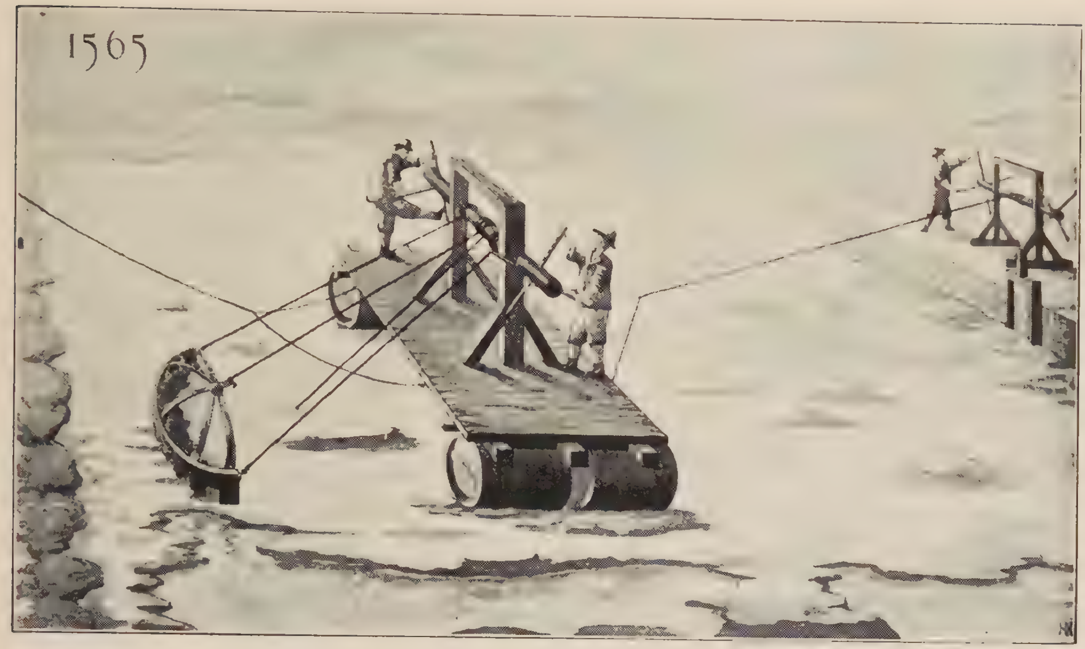


FIG. 4.

excavate very hard and stiff kinds of soil. The capacity of this bucket has been increased to more than 11 cubic metres.

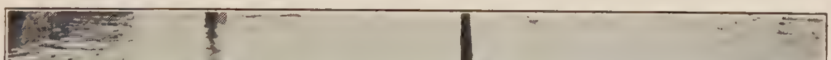


FIG. 5.

GRAB DREDGER

Besides the "bag-and-spoon" dredger these old illustrations show also a kind of grab-bucket (*vide* Fig. 2), consisting of two halves hinged at the top to enable them to be opened and closed at will. The open grab was let down forcibly to the surface of the ground to be excavated, and was then closed, so that it was filled, more or less, according to the softness or hardness of the soil; it was then raised and opened again to discharge its contents.

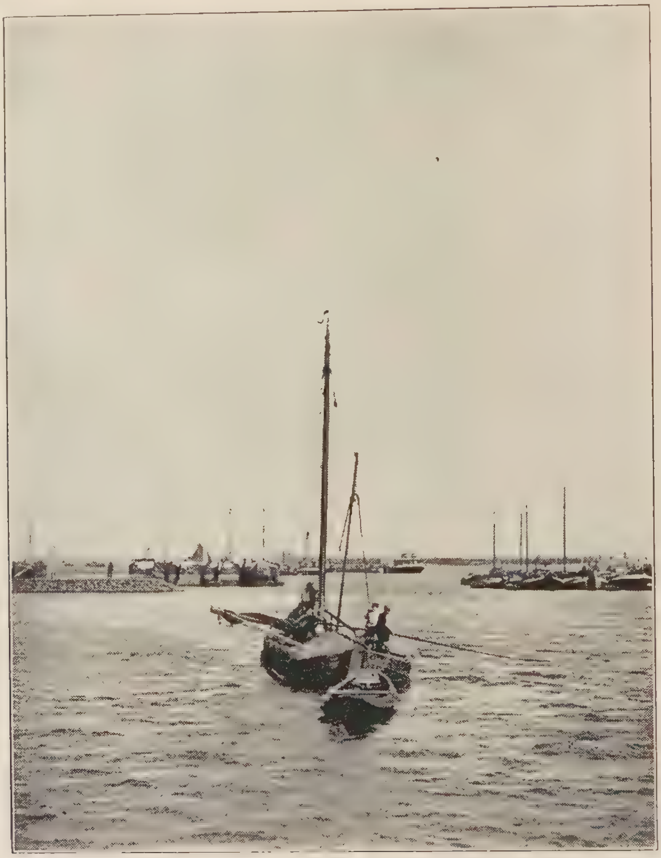


Fig. 6.

This system, also, has been much improved, and finally it led to the well-known Priestman grab-dredger, which, at present, is still extensively used, not only in the discharging of bulk cargo, etc., but also in many cases where large masses of soil have to be excavated, as, for instance, the maintenance of proper depths of harbours. In these cases several grabs are placed together on one vessel.

Only recently the grab-bucket rendered excellent service at the Zuiderzee works in removing *keileem*—a kind of boulder clay, a diluvial product—in the construction of the dike which joins the Island of Wieringen to the mainland; grabs were used with a capacity of 2½ cubic metres.

The main principle of the Priestman appliance is that the grab can be hung at will from either of two chains. If the bucket should hang from one it opens itself; if suspended by the other, it closes, so that by the process described a maximum of speed, attended with the utmost simplicity, is attained. The capacity of this bucket, too, has been increased to about 5 cubic metres, while its construction can be adapted to the various kinds of soil that have to be removed.

Fig. 7.

In Germany especially the grab-dredger has found an extensive use in unloading mud or sand from flat-bottomed barges, whereby the bucket moves along a conveyor over a long distance so that it can be discharged at any point.

MUD RAKE

Yet another way to excavate ground in running water is by raking the soil loose where it must be removed, after which it is carried along by the current (*vide* Fig. 4). This method, too, has often been used with success in later times (Figs. 8, 8A.). In the mouth of the River Solo, for example, what is called a mud rake was used for a considerable time. This is a wheel with scrapers which was continually dragged over the bottom by a tug wherever a new channel was wanted or the depth of the water had to be increased.

MUD DREDGER

When examining yet more old illustrations we find in the first half of the seventeenth century a mud dredger, which more than any of the preceding appliances, leads up to the bucket dredger. In a book on the history of shipbuilding by E. van Konijnenburg, C.E., M.Inst.C.E., we find an interesting treatise on this subject. Mr. van Konijnenburg states that the old mud dredger already existed in the first half of the seventeenth century, and that it was the forerunner of the bucket dredger (Fig. 9, after an old engraving by E. Vermorcken. Fig. 10, after an etching by R. Zeeman).

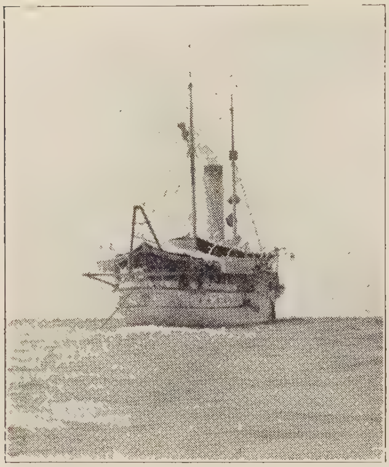


Fig. 8.

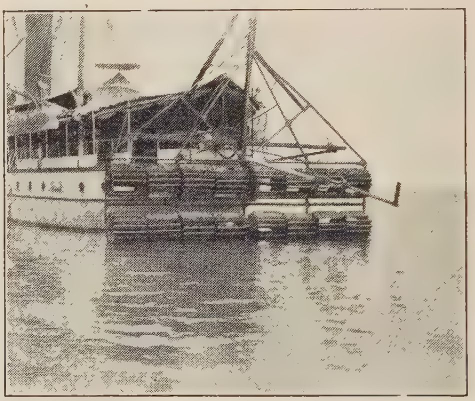


Fig. 8a.

This mud dredger, which at first was worked by hand, was afterwards operated by horses, and had, as was thought at that time, attained a state of great perfection in the eighteenth century. As late as 1829 a vessel was built by Kater Bros., at Monnikendam, which could dredge to a depth of 7 metres and was worked by three to six horses.

The same builders are said to be the inventors of the first hopper barges, about which we shall speak later.

Jan Jansz. Nieng, Burgomaster of Hoorn in 1632, is also mentioned as the inventor of the mud dredger, and a model may be seen in the West Frisian Museum in that town.

Finally, an engineer, Adam Clippens, from Ghent (Belgium) is mentioned, who, about the same time, built a mechanical mud dredger.

Leaving the question undecided as to who is the real inventor, it appears from all this that the mud dredger was frequently used in Holland and maintained its position for a long period. It is known that about the year 1850 a machine of this kind was used in the "Groot-Noord-Hollandsch" canal, the old route from Amsterdam to the sea, and the vessel accordingly bore the name of "*Het Groote Kanaal.*"

This vessel was built of wood and equipped with a well, in which a shoot could be made to move up or down. The shoot had its pivot on the deck, and could be raised or lowered by means of a hand winch. Small paddles attached to an endless chain worked in the shoot, and the chain was operated by horses walking on the deck of the vessel in a kind of churning mill (Fig. 11).

At its bottom end the shoot carried an iron or steel shoe to rake loose the ground that had to be dredged, and the excavated material was afterwards conveyed by the paddles along the U-shaped shoot until, when it had reached the top, it fell down into a kind of trough or shoot, which led to barges lying alongside or astern of the vessel, which could hold from 10 to 12 cubic metres of earth. These boats were afterwards discharged by hand.

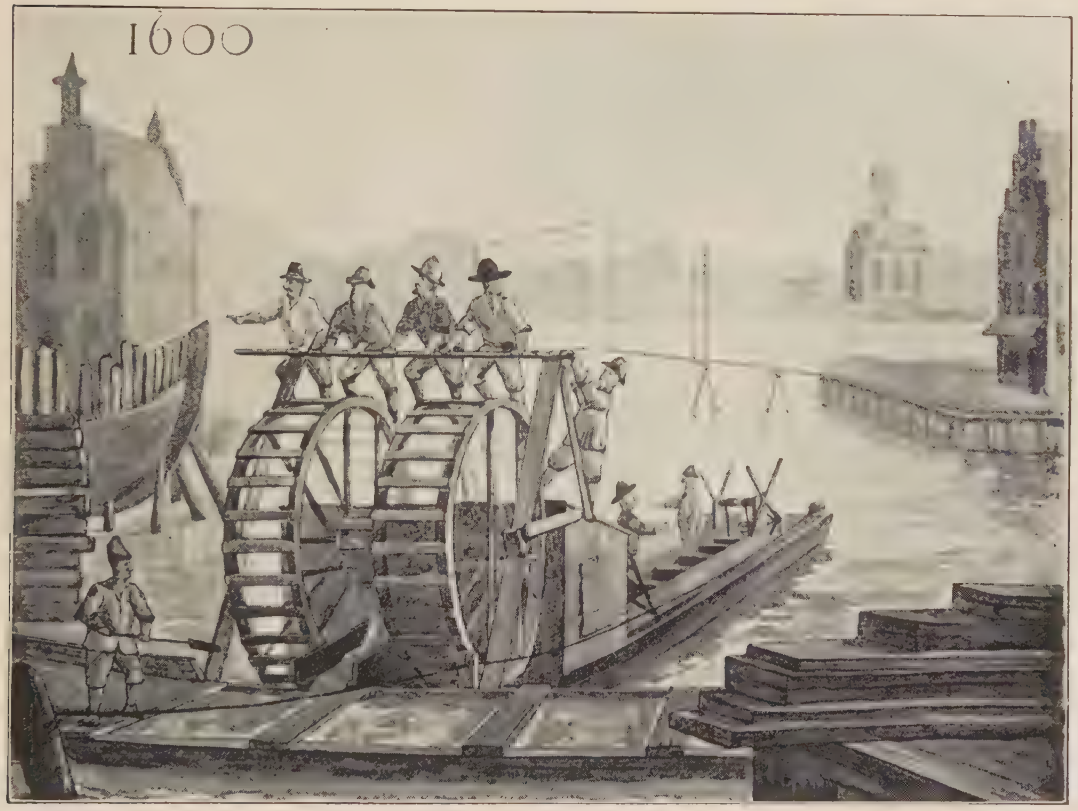


Fig. 9.

It may be mentioned that, singularly enough, about 1910, a dredger on this principle, steam driven, was working in the silted-up parts of the harbour at Bremen. It had been constructed in 1861 by the firm of G. Waljen at Bremen. As far as is known, steam power was never used in the mud dredger in Holland (Figs. 12, 13).

It is said that in this way 300 or 400 cubic metres of earth were excavated per day.

It may be readily seen from the illustration that this machine could only work with a front and rear chain, and, therefore, was only fit to dredge parallel furrows at varying depths.

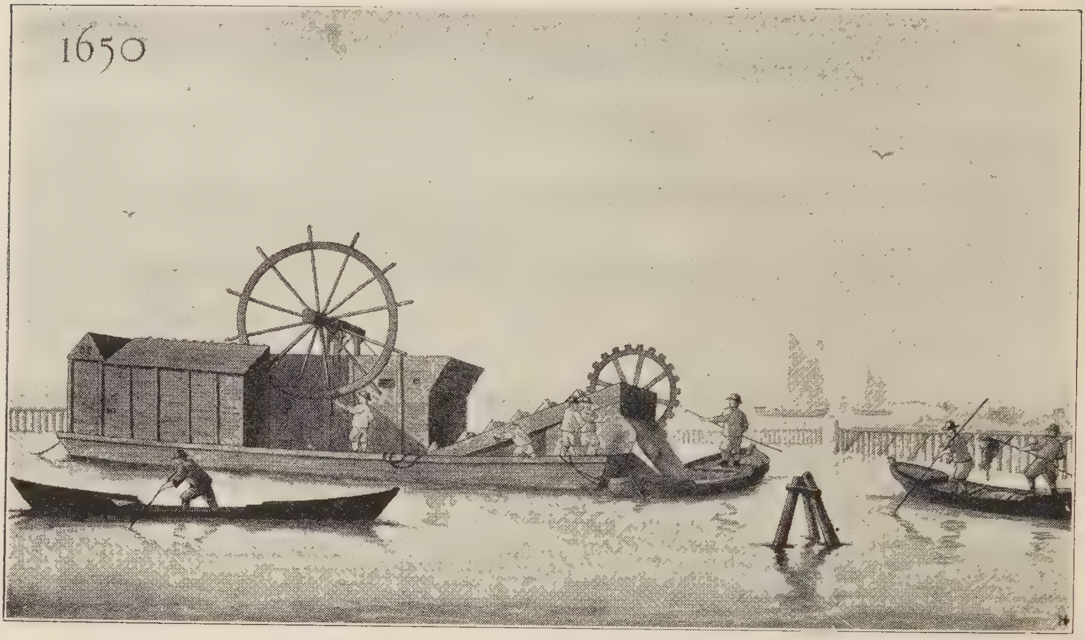


FIG. 10.

In the second half of the nineteenth century people began to look round for machines that could lift excavated material above the water level, and owing to the exigencies of the time they were greatly improved and enlarged. This was caused mainly by the fact that many great works had to be executed, by reason of the continued increase in the draught of sea-going ships, to which the depth of the mouths of canals and rivers and of the harbours had to be made to correspond. Competition, too, has had a large share in bringing about improvements, and will also in the future be an important factor.

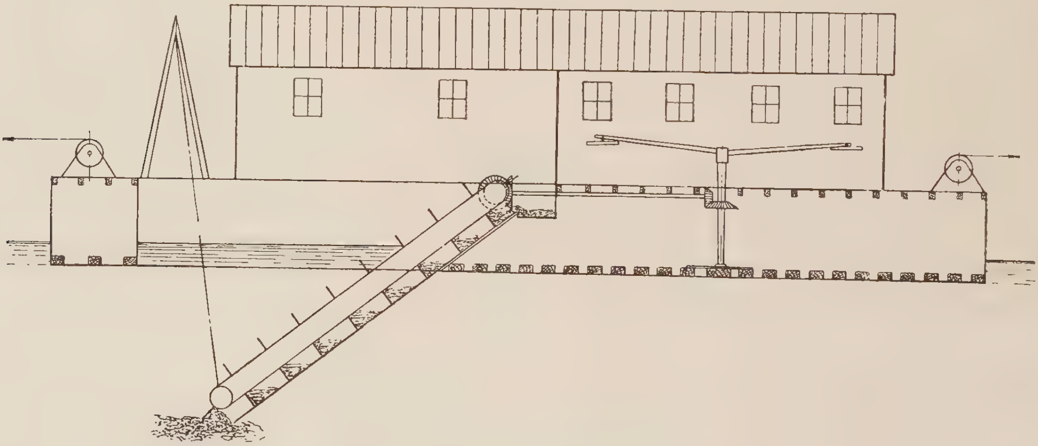


FIG. 11.

Not only to engineers, shipbuilders and contractors, but also to many workmen, the dredging industry has given an abundance of work. In fact, so many people are employed in this manner that it may be looked upon as a trade to itself, and has claimed a place in the curriculum of trade schools like any other branch of engineering. That the crew of the dredgers, and especially the dredger masters, or captains, have largely contributed to the practical improvement of the various kinds of appliances, will be also readily acknowledged by everybody.

DREDGER WITH VERTICAL LADDER

Where ground that has to be excavated is very hard, little can be accomplished with the old mud dredger. Hence we find, a few years later in the canals of Amsterdam, a machine which differs widely from the preceding, but which brings us to a type a good deal nearer in design to the present bucket dredger. The original designer is not known, and it must be assumed that some practical dredger master or other introduced this new method (Fig. 14).

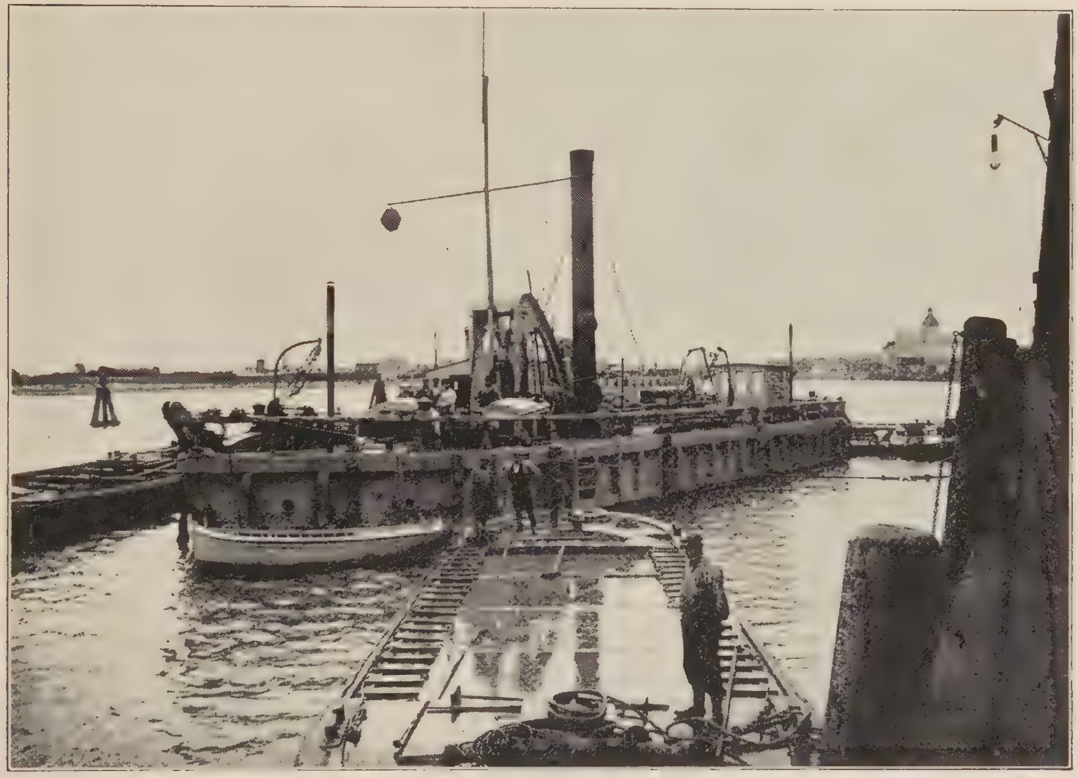


FIG. 12.

Here, again, we find a wooden ship, in the centre of which there is a short open well, containing a wooden frame which could be made to move up and down. This frame was supported by a wooden structure consisting of four strong beams firmly braced together.

The wooden frame carried at its top- and bottom-ends square tumblers and shafts.

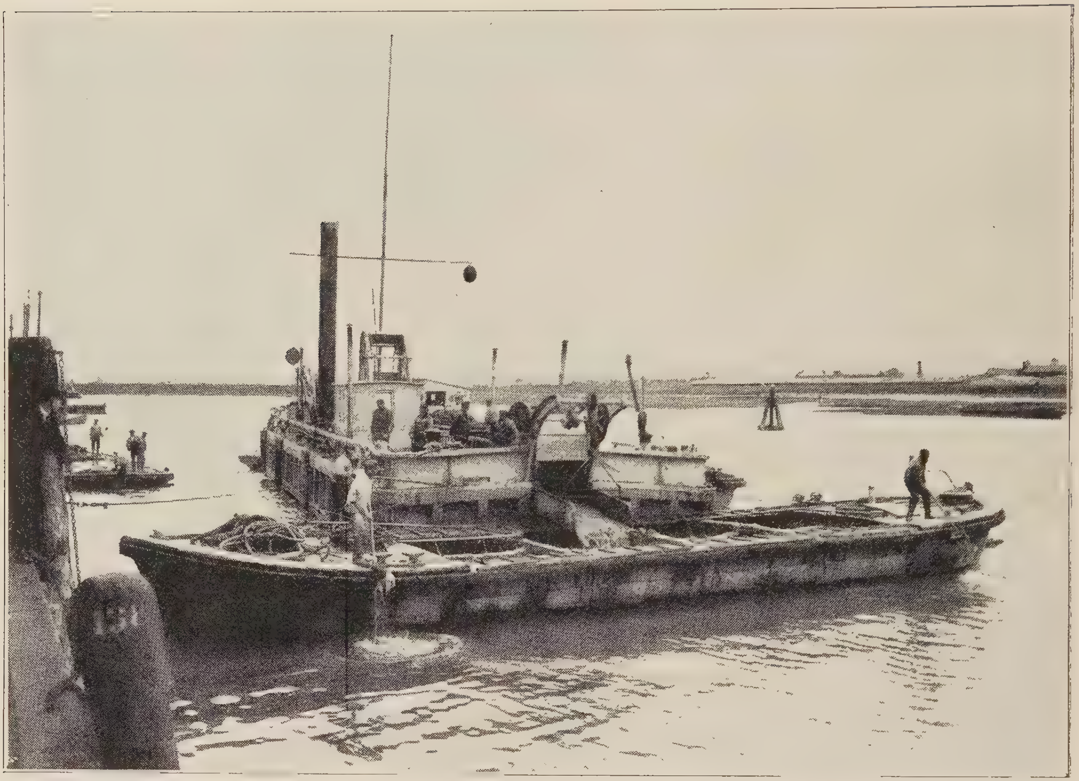


Fig. 13.

Over these ran an endless chain consisting, for the greater part, of links, and to every sixth set of these links a sheet-iron bucket was attached. This link-and-bucket chain was worked by means of an engine placed on the deck. The buckets discharged the dredged material into a shoot, which at its top had a movable part. This movable part

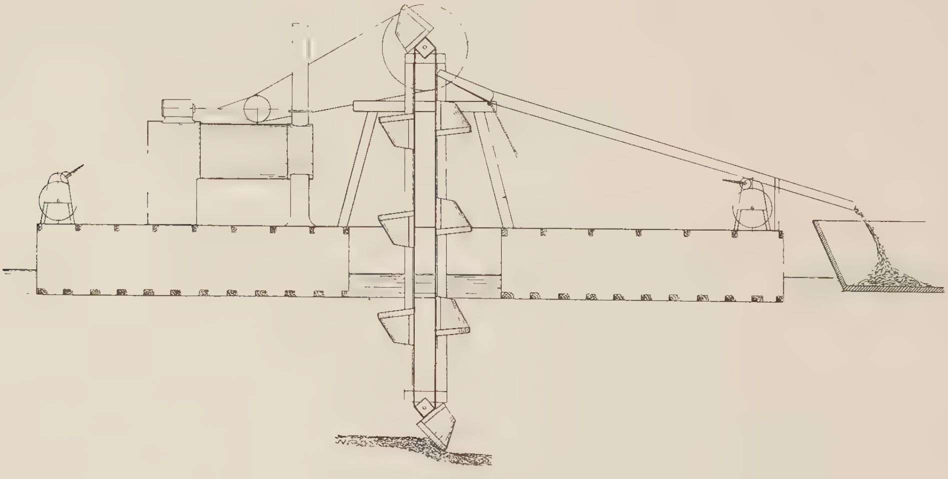


Fig. 14.

could be alternately lowered to receive the dredgings or be raised again to pass the empty bucket.

On the deck hand winches were placed which could not only move the vessel backward or forward, but also sidewise ; the last movement becoming possible owing to the introduction of the bucket chain. This machine did its work, then, on a small scale, just as the largest dredgers do it now, in so far as the method of working with the chains is concerned. That is to say the dredger was moved by the frontside chains alternately to starboard and port, and with each reversal was pulled a little farther into the area that had to be dredged by the front or bow chain. The rear chains kept the vessel in the most desirable position, and at the same time prevented the vessel from being pushed too strongly by wind or current, against the ground that had to be excavated.

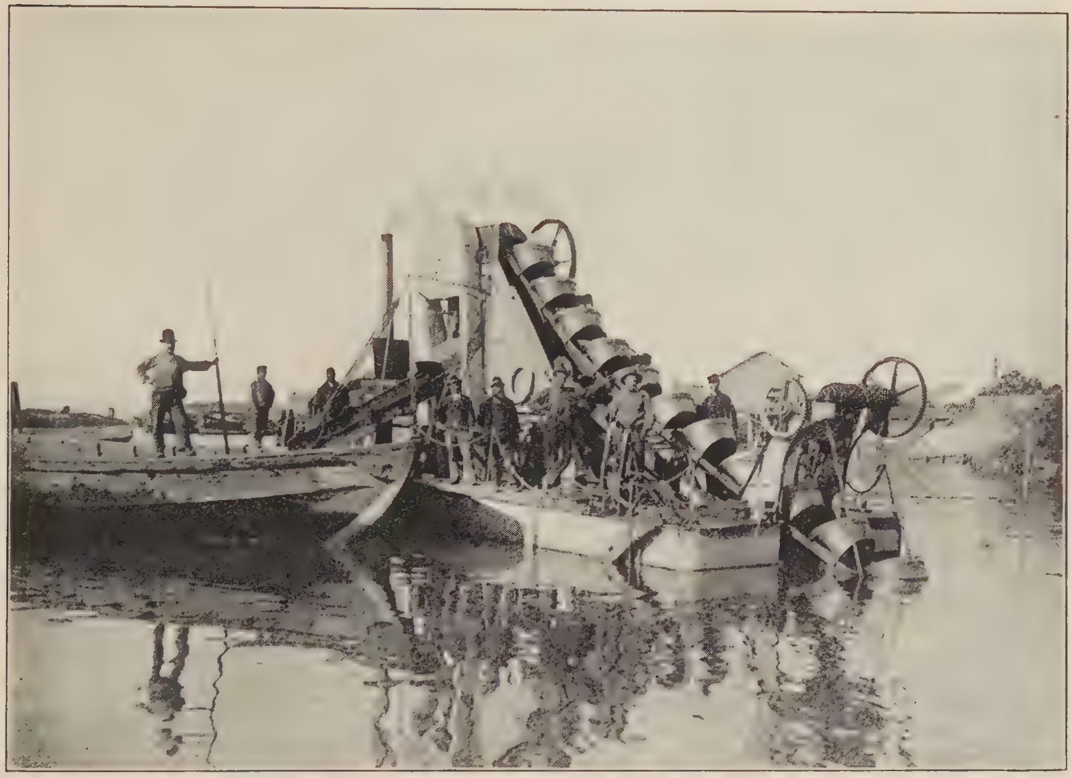


Fig. 15.

Everybody will understand that the three front chains did the most important work.

The dredged material, about 20 to 25 cubic metres per hour, was again delivered into small vessels which were discharged by hand.

By this method the soil could be removed evenly from the bottom without any ridges remaining, which could not be avoided with the mud dredger described above, and it also had the advantage that it became unnecessary to move the dredger continually backwards, which saved time. With the grab dredger this regular way of working could not be attained.

DREDGER WITH INCLINED LADDER

With the last-mentioned example before us, it is not very difficult to follow the successive improvements which led to the modern bucket dredger. What follows here is a description of such a dredger built about the year 1875 (Fig. 15).

The principal alteration, without doubt, was that of the well, which was lengthened in front, sometimes even as far as the forepart of the ship, and the two types were distinguished as " closed " and " open " (Figs. 16, 17).

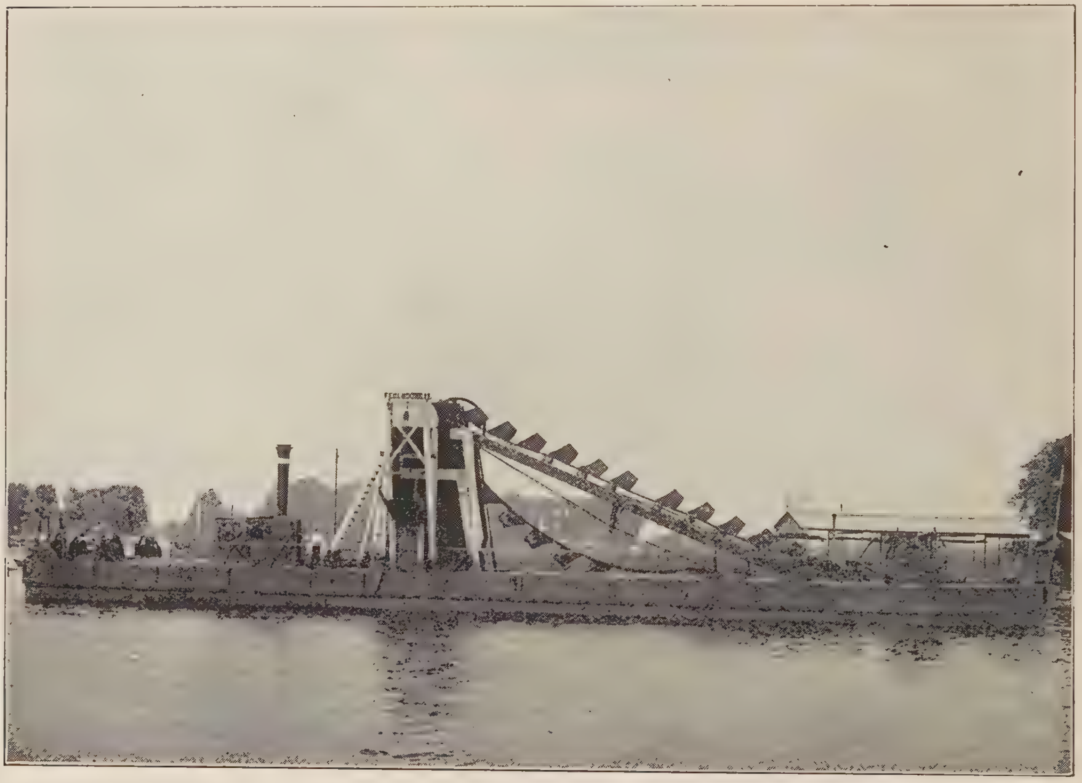


FIG. 16.

The framework, or, properly speaking, the " bucket ladder," was placed in a slanting position, which made it possible to place the shoot under the buckets in such a way that they discharged their contents into it. This made the plate superfluous which, in the old vertical type, had to be inserted every time a bucket passed to receive the excavated material. The shoot was made in such a way that the dredgings could be delivered in a very simple manner, either to starboard or port, by opening a door, called the shoot door.

The bucket ladder swung at its top end round the tumbler shaft, while the bottom end was suspended from chains operated by a hand winch mounted on the forepart of the vessel.

The link chain had now in reality become a bucket chain, since the long distances between the buckets had become unnecessary, on account of the improved shoot. In this system the complete chain was comprised of buckets and links placed alternately.

Later still the possibility was considered of leaving out the intermediate link altogether, so as to get a continuous bucket chain, but, although this is done in some special cases, for example, in tin-dredgers, it is of no advantage for ordinary dredging purposes. It necessitates a very heavy bucket chain and proportionately no more work is done, since the capacity of the bucket has to be made smaller with a chain of the same pitch. It is of greater advantage to retain the intermediate link and to extend the bucket as much as possible in front and at the back over this link, so as to give it the greatest possible capacity. Thus the capacity is increased without the drawback mentioned above.

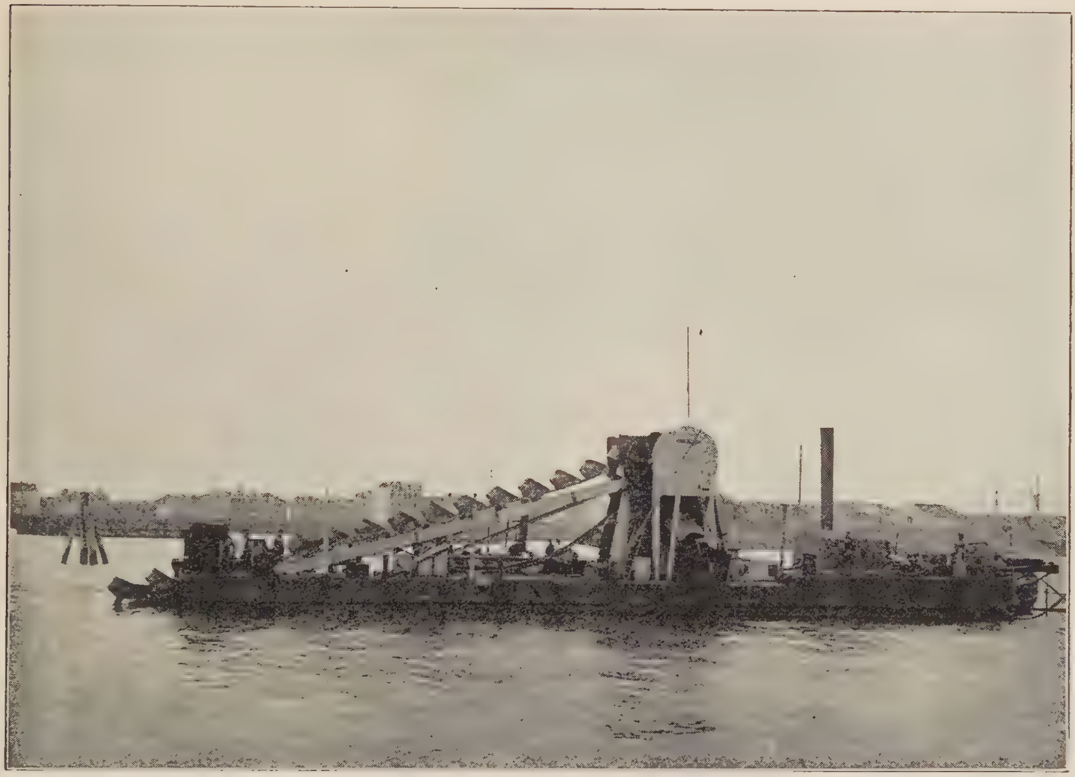


FIG. 17.

Below, a horizontal or inclined engine with one or two cylinders was provided to work the bucket chain, the power being transmitted by fitting a large cast-iron spur wheel on the shaft of the upper tumbler which was driven by a cast-iron pinion, and which in turn was driven by belts from the steam engine.

Steam was supplied by a Galloway boiler.

On deck five hand winches were placed : two for working the front side-chains, two for the rear chains and one for the hind chain. The bow or front-chain drum was worked by the main engine by means of a ratchet gear.

The capacity of the buckets amounted to 200 litres at most.

DREDGER WITH DOUBLE LADDER

Another way to increase the capacity consisted in building two wells in the vessel, each equipped with a complete bucket-ladder and bucket-chain, by which apparently the output was doubled.

The drawbacks connected with this system were, however, so serious that it was not retained, and the later dredgers were equipped with only one bucket ladder.

In the first place one bucket chain alone requires the undivided attention of the dredger master, hence it is difficult for him to attend to another one.

Secondly, two chains require double upkeep, and, finally, the ships become very wide. For, to their own width, the width of a barge on each side must be added, the one bucket ladder conveying the spoil to starboard and the other to port. When working in harbours this was especially a serious inconvenience.

To meet the latter difficulty a dredger was built without a well, a bucket ladder being mounted on both sides of the vessel.

Only recently one could see an old dredger of that type at work near Rotterdam, which served to dredge river sand into ships.

This system, however, was never followed where large quantities of material had to be dealt with.

HOPPER BARGES

With regard to the progressive development of dredgers the same may be said of the barges into which the dredging material was delivered. Not only had their capacity gradually been increased from 30 to 50 cubic metres, but a very simple and ingenious method had been invented to unload the barges in deep water by means of hinged doors in the bottom (Fig. 18). Hence the name “ door ” or “ hopper ” barges.

Between the prow and the stern the air compartments and the hold are to be found. Over the hold a shaft runs lengthwise, round which chains are wound from which the above-mentioned doors are suspended.

The shaft is attached at one end to a ratchet gear. By the simple removal of a pawl from the ratchet-wheel, the doors will fall open and discharge the contents of the hopper. One door is slightly wider than the other and when closed they overlap. To prevent the doors fouling each other during the closing operation the suspension point of the crosshead from which they hang is placed out of centre, the longer end of the crosshead being attached to the wider door.

Up to that time wooden ships had been nearly always used for dredgers and barges. These were gradually replaced by iron ones, and still later by steel vessels. Yet, for a long time iron was preferred, since iron corrodes less than steel ; for it must not be forgotten that it is next to impossible to keep the ships properly painted when in use, while circumstances bring them to places where the water corrodes the plates very badly.

DREDGER OF 1884

It is clear that a useful piece of machinery like the dredger, which was becoming more and more used, had to undergo great improvements. These were not long in coming, and, of course, many improvements were regularly introduced into the existing machinery. But it is our intention to give only a description of the dredgers which were built in 1884 for the La Plata harbour works in the Argentine, and the changes which had taken place up to that date will at the same time be more clearly illustrated (Fig. 19).

The ship, as well as the deck, the main frame and the bucket ladder, were all made of iron or steel. The bucket chain was, as is the case now, no longer hung from the upper tumbler, but was supported by ladder bearings, placed against the main frame. Although, theoretically, this is no improvement, as the result is a somewhat broken line of the bucket chain, yet this design is generally preferred, chiefly because the top tumbler can be more easily replaced. The drawback mentioned was met by mounting an auxiliary ladder, which we shall discuss in detail later.

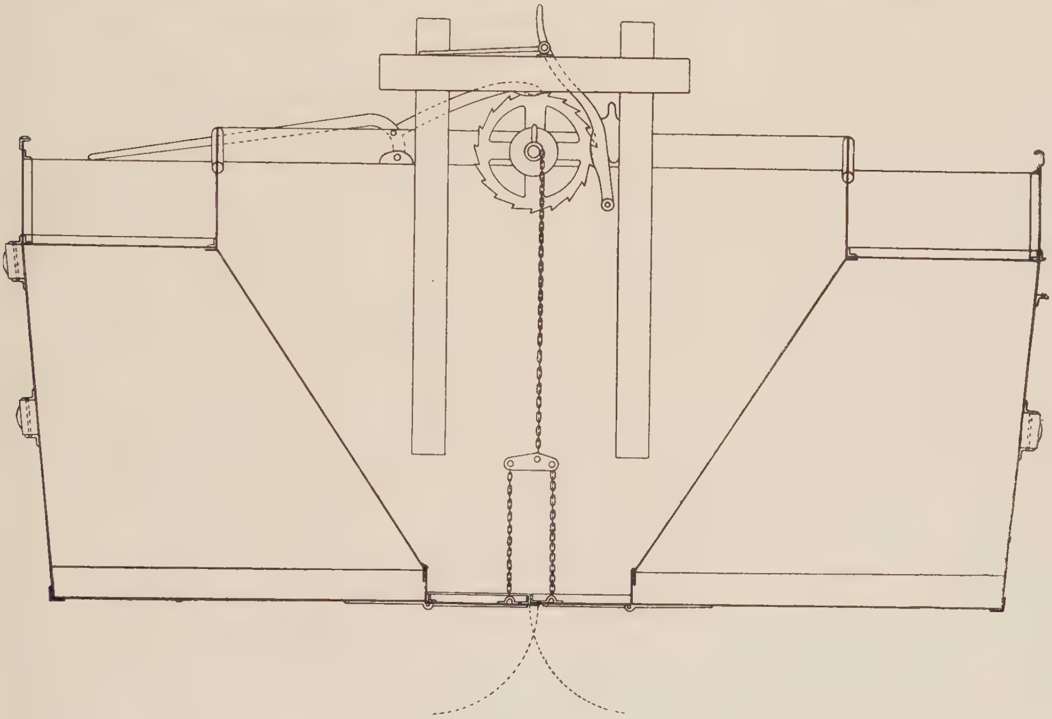


FIG. 18.

The bucket ladder was lifted and lowered by steam power, while the hand winches on the deck were replaced by steam winches, all working with one cylinder. The transmission was usually effected by means of a worm shaft and worm wheel.

The capacity of the buckets had been increased to 300 litres, and the bucket chain was worked by a horizontal compound engine with condenser, while the boiler was an ordinary flue boiler. The dimensions of these dredgers were approximately as follows :

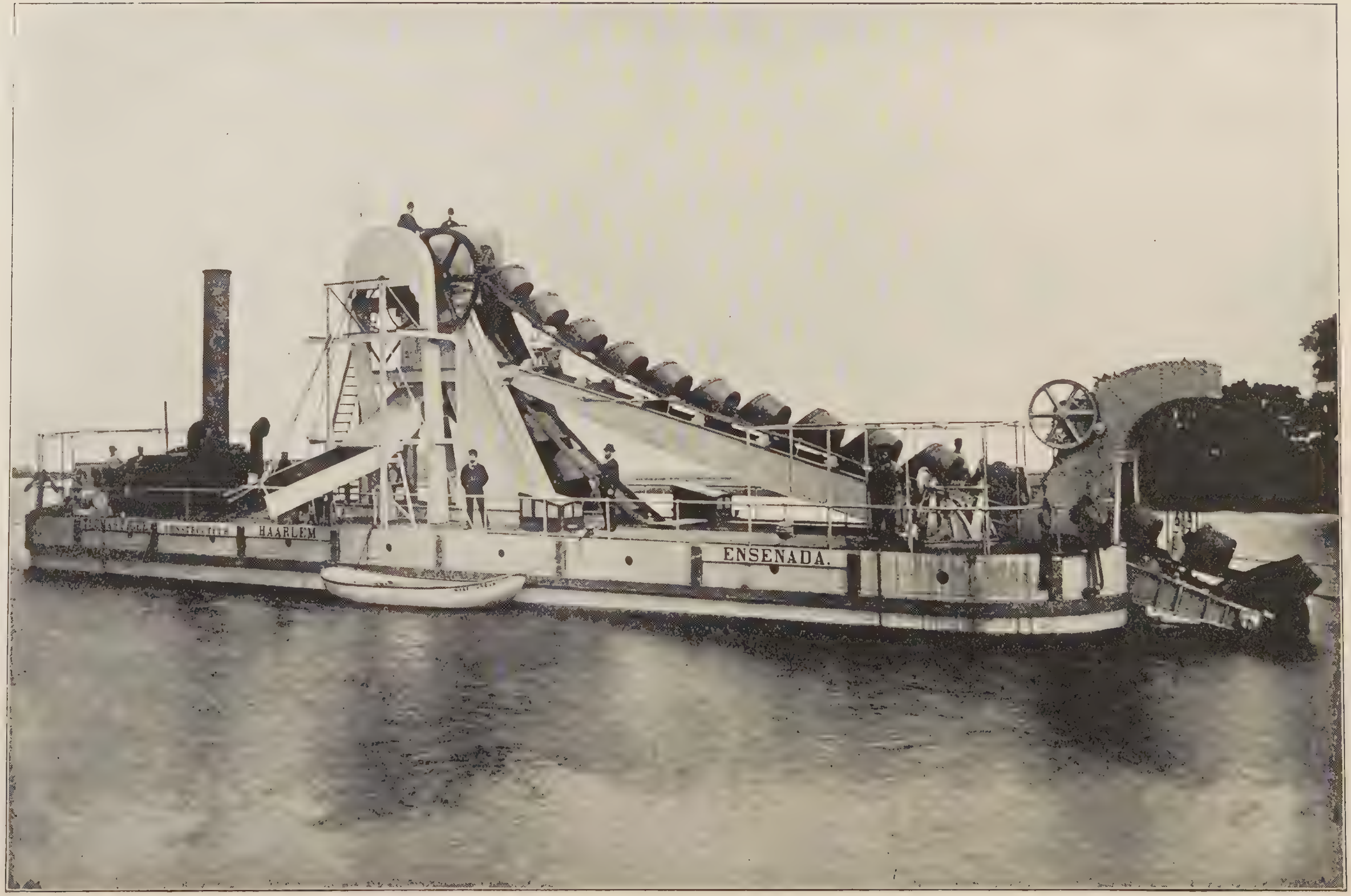


FIG. 19.

Length of ship	35 metres.
Width	6 metres.
Depth	2·7 metres.
Main engine	150 I.H.P.
Boiler	60 square metres heating surface.
Pressure	6 atmospheres.

For the above-mentioned harbour works six dredgers were despatched; three of them were shipped in parts which were riveted together at the place of destination; two were completely taken to pieces, and the plates and frames re-assembled afterwards; whilst the last of the six, the *Buenos-Ayres* No. 3, was entirely built as a seaworthy ship, and reached its destination under its own power (Fig. 20).

This dredger was one of the first that made the voyage in this way, and this method in after years was much preferred, as it facilitates the delivery of this material to nearly every part of the world.

If every care and precaution were taken at the beginning, such as dismantling the superstructure as much as possible, it was soon found that the removal of the bucket chain was all that was necessary and, when taken to pieces, could be stored in the hull of the ship. With very large dredgers this even was not thought necessary, and it was considered sufficient to fasten the chain securely against the rolling of the ship. To make the latter more seaworthy a mast and sails were rigged up.

With this type of vessel the well could, if desired, be built either fore or aft; in the latter case there were a propeller and rudder on both sides of the well, and the two rudders were connected.

In most cases the well was closed during the voyage, so that greater storage room was obtained for coals, buckets, etc. The temporarily closed bottom could be removed without the necessity for docking the ship when it reached its destination (Fig. 21).

Of late years large dredgers have often been towed across the ocean without any temporary alteration whatever.

For a long time the maximum width of dredgers was limited to 6·50 metres, because this dimension enabled the vessels to reach the principal dredging places in Holland, and to pass through the canals. The width was afterwards increased to 7·50 metres, this being the maximum available on the Amsterdam to Rotterdam inland waterways. Owing, however, to the demand for dredgers of greater capacity, this limitation in regard to width had to be abandoned. Moreover, much against their will, dredger builders found they had to construct dredgers possessing all the qualities of sea-going vessels. The first sea trips attempted were only for short distances, and in the vicinity of the yards where they were built. Gradually, however, these trips extended to neighbouring countries until, at the present day, it is quite common to hear of dredgers being towed by steam tugs to such places as China, the Dutch East Indies and South America. In fact, there is no limit to the distance to which they may be sent. Needless to remark, it is essential that dredgers which have to travel long distances by sea must be built strong enough to withstand the buffeting of any heavy seas they may have to encounter while on their journey.

With regard to this method of ocean transport the Dutch tug companies enjoy a world-wide reputation.

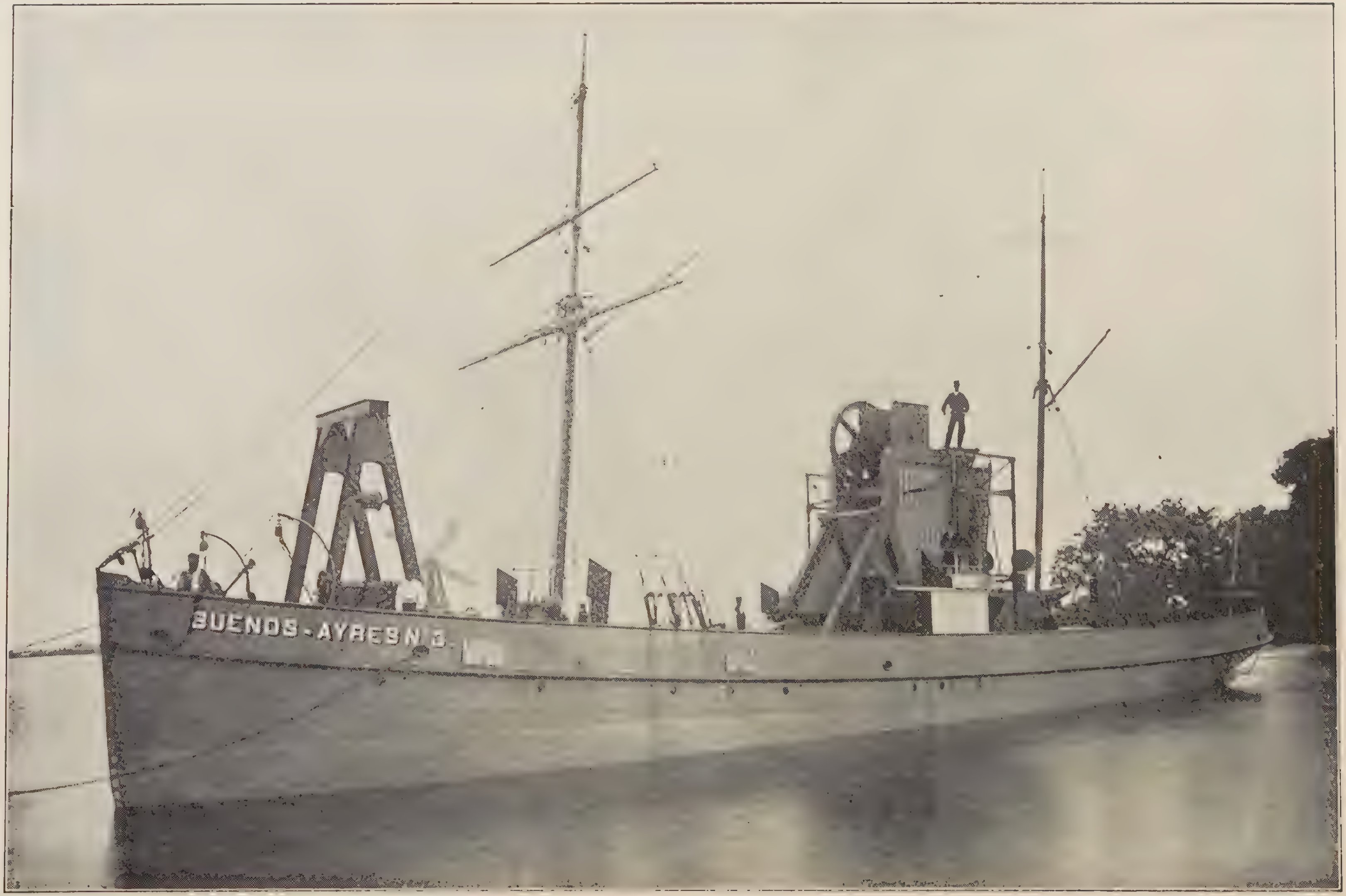


Fig. 20.

Before proceeding to explain the further development of these dredgers it is necessary to examine the barges into which the dredged material is delivered. Here, too, many changes have been wrought since their first inception.

For instance, it was found necessary to increase the capacity of the hopper barges, which have already been described, to 70 cubic metres ; as time went on the capacity rose to 80 cubic metres with eight sets of doors, and 100 cubic metres with ten sets of doors. In order to be able to use these hopper barges a deep-water depositing ground was required, and once this had been filled and no new place of discharge being available, other means had to be thought of to get rid of the dredged material.

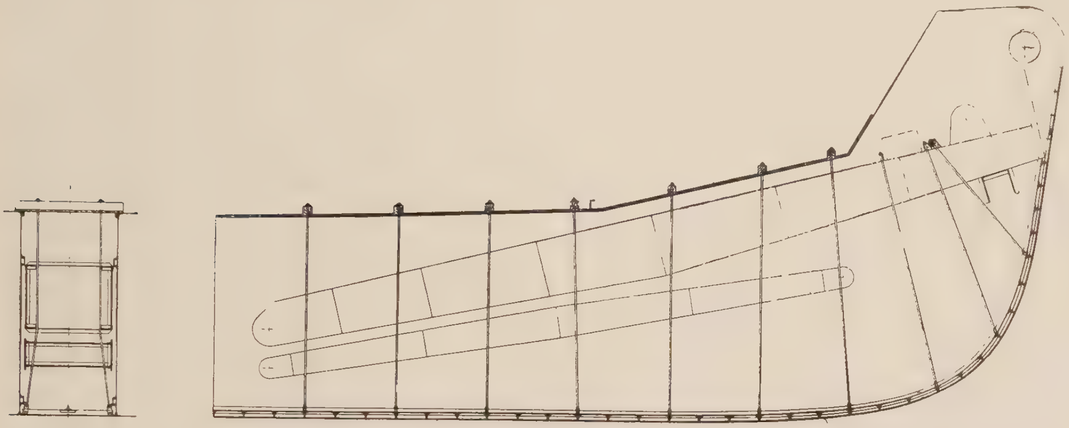


Fig. 21.

This difficulty has been met by replacing the hopper barges with vessels similar in type, but with the difference that the doors, when opened, do not project beyond the bottom of the barge (Fig. 22). This invention, however, is no use where circumstances demand some means whereby the dredged material can be dumped on the shore.

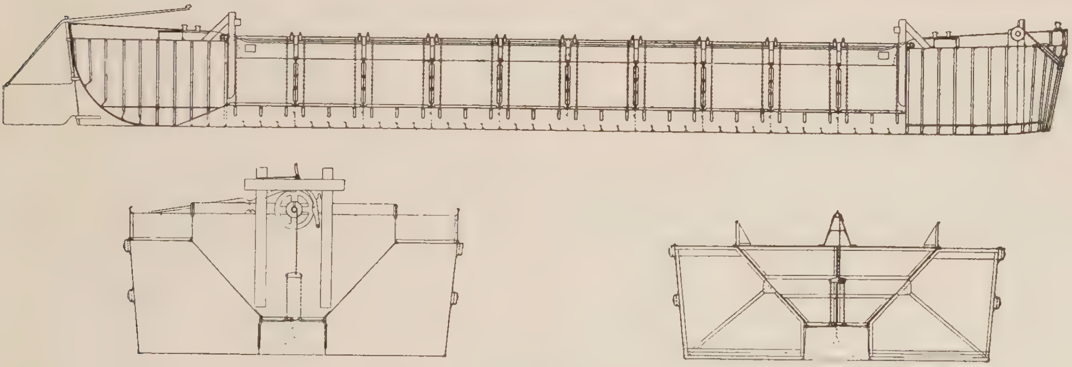


Fig. 22.

DREDGER WITH LONG SHOOT

Other methods which have been used for depositing the dredged material are described below. To begin with, there is what is called the " dredger with long shoot." This is a common dredger with a shoot attached as high as possible to the top tumbler and connected with an open shoot about 30 or 40 metres long ; the framing carrying the shoot is supported on a separate barge moored to the dredger, whilst the crane is also moored to the dredger (Fig. 23).

In order to convey the dredgings ashore, a powerful jet of water from a centrifugal pump is directed into the shoot from a discharge pipe of from 20 to 25 centimetres in diameter.

This dredger raises soil which is discharged in front by means of hopper barges. At present this method is very seldom used.

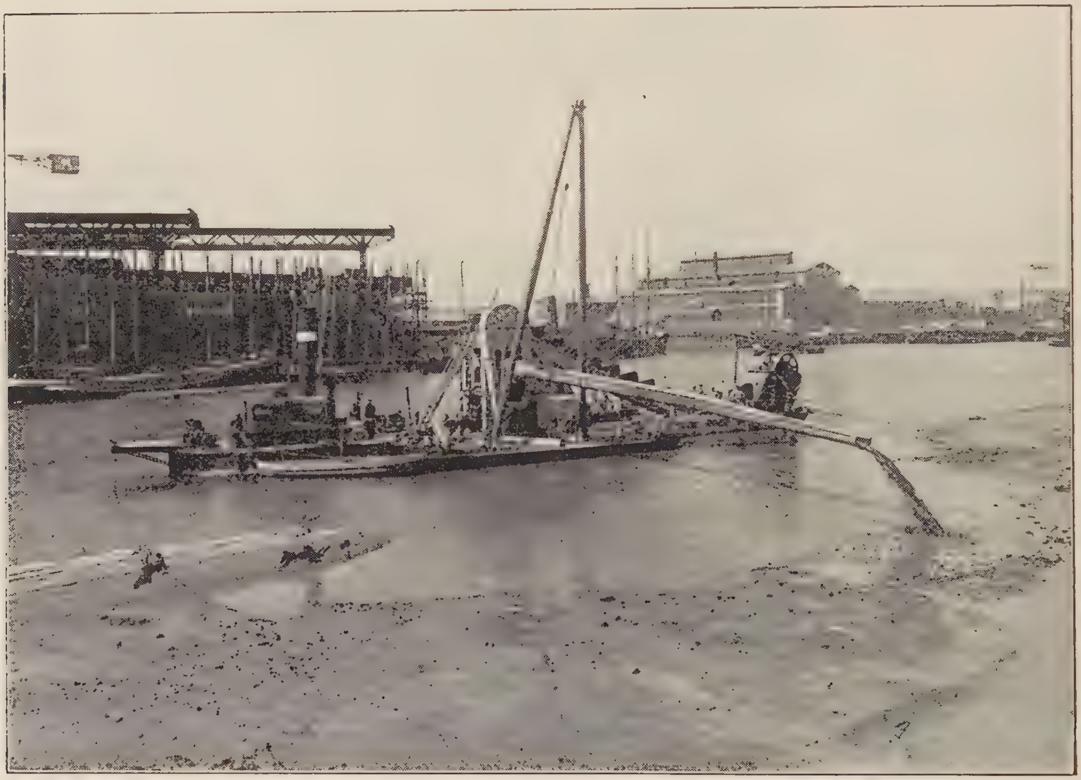


Fig. 23.

When a canal is already made the dredged material can be immediately deposited by means of the long shoot dredger behind the dykes.

According to the " Encyclopædia Britannica " this method was first used in making the Suez Canal ; the open shoot had a length of about 70 metres with a fall of 1 in 20.

In North America the same method has often been used with a similar shoot on each side of the dredger.

When it was not possible to make the fall of the long shoot sufficient to deliver the mud on the depositing ground, a conveyor was sometimes used, which was driven by an independent engine and was placed in such a way that the mud was directly deposited on to it from the centre shoot ; also, in this case, a vessel for carrying this heavy plant was moored alongside the dredger (Fig. 24).

Another very simple way to unload the barges was by using tip buckets, which were filled with shovels in the barges, lifted by means of a steam crane, and discharged on the shore. The tip buckets were sometimes placed side by side in vessels specially constructed for that purpose so that they could be filled directly by the dredger.

A third method of discharging was by means of an elevator called a "Jacob's ladder." In case any one should be under the misapprehension that this name is associated with the first constructor of this piece of machinery, it may be well to point out that the origin can probably be traced to the Biblical story of the dream of the Patriarch Jacob (Fig. 25).

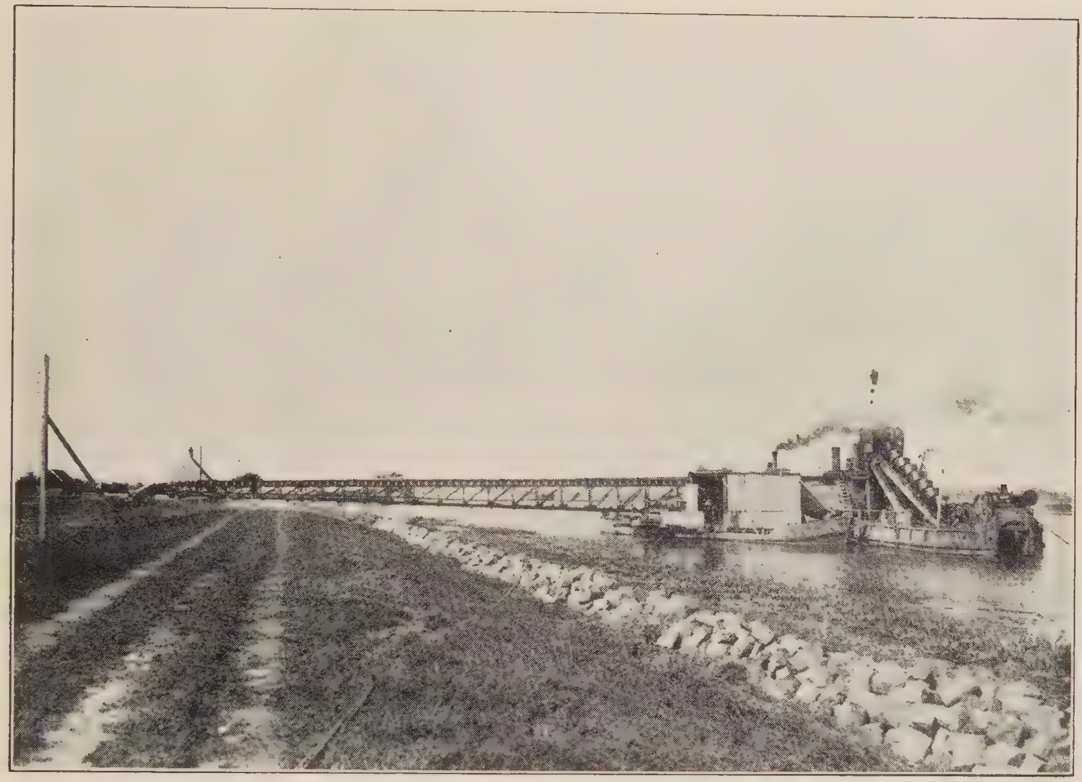


Fig. 24.

JACOB'S LADDER

By means of the Jacob's ladder the soil can be directly conveyed from closed barges which are similar in shape to the hopper barges, with the difference that, instead of having doors, the flat bottom is closed, and consequently the hold is entirely free of all chain gear.

The machine consists essentially of a wide vessel, in the centre of which a structure is erected. Round the top end of this structure a ladder with buckets of 100 litres capacity can be made to move on a hinge.

This ladder forms a right angle horizontally with the longitudinal axis of the vessel, and the ladder turns round its centre. The barge which has to be unloaded is moored alongside the vessel; the ladder is lowered into it, so that the buckets can dredge the material from the barge and convey it to the top end of the ladder, where it is discharged into a shoot.

The Jacob's ladder is still often used, for example, in discharging sand from ships and depositing it on the bank, for conveying gravel from ships into railway trucks, and also for conveying coal direct from the lighters into steamers.

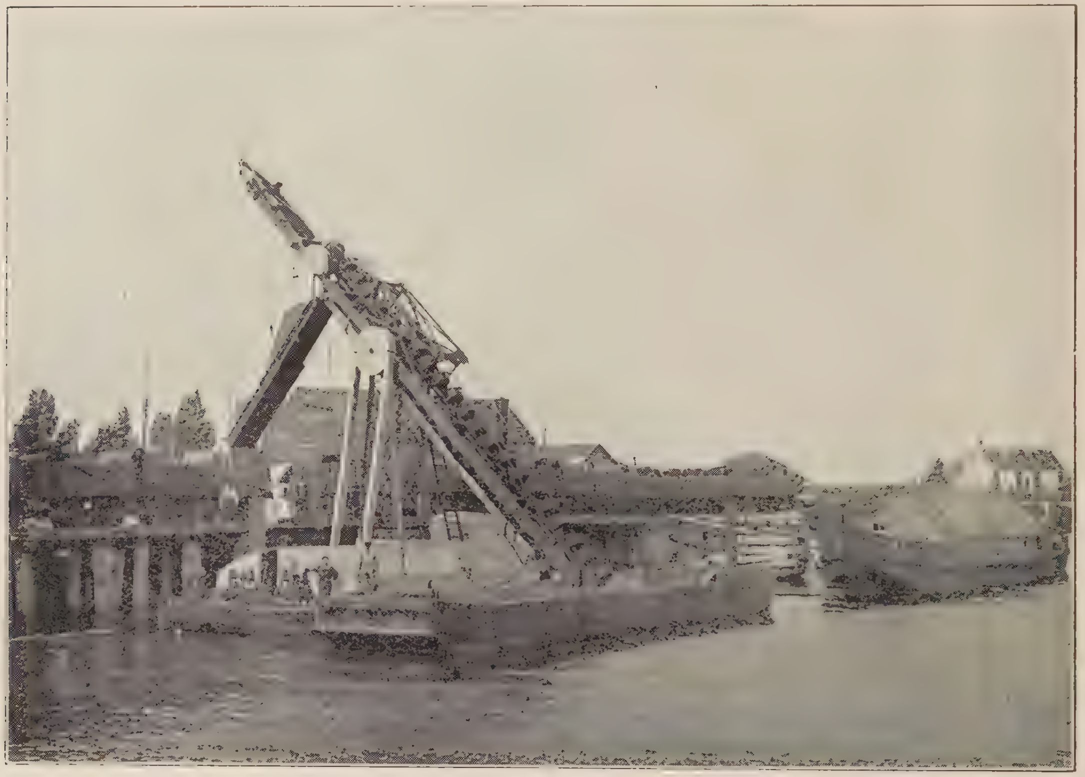


Fig. 25.

It is not surprising, therefore, that improvements have been introduced, chiefly consisting in replacing the ordinary steam engine as driving power by a modern compound engine with condenser, etc., while the hinged ladder has been replaced by one, of which the bottom part, that part which is lowered into the barge, only is hinged (Fig. 26). With a view to negotiating bridges the whole ladder structure revolves, so that the bucket ladder can be moved into the longitudinal axis of the vessel. It was possible, however, to do this with the first-mentioned type as well.

ELEVATOR

The most common way to discharge barges, at one time, was by means of the "floating" or "stationary" elevator, named according to whether the elevator was built on a floating vessel or upon a foundation of piles. This appliance is also used for dredging materials from barges (Fig. 27).

The floating elevator consists of two vessels on which a structure is built in such a way that a loaded or empty barge can move freely between the two. This structure carries a complete bucket ladder with the usual appurtenances, which can be lowered in a longitudinal direction into the barge lying between the two boats. The material dredged from the barge is, as with the long-shoot dredger, washed through an open shoot by means of a strong jet of water to the depositing ground; the shoot being about 40 metres long.

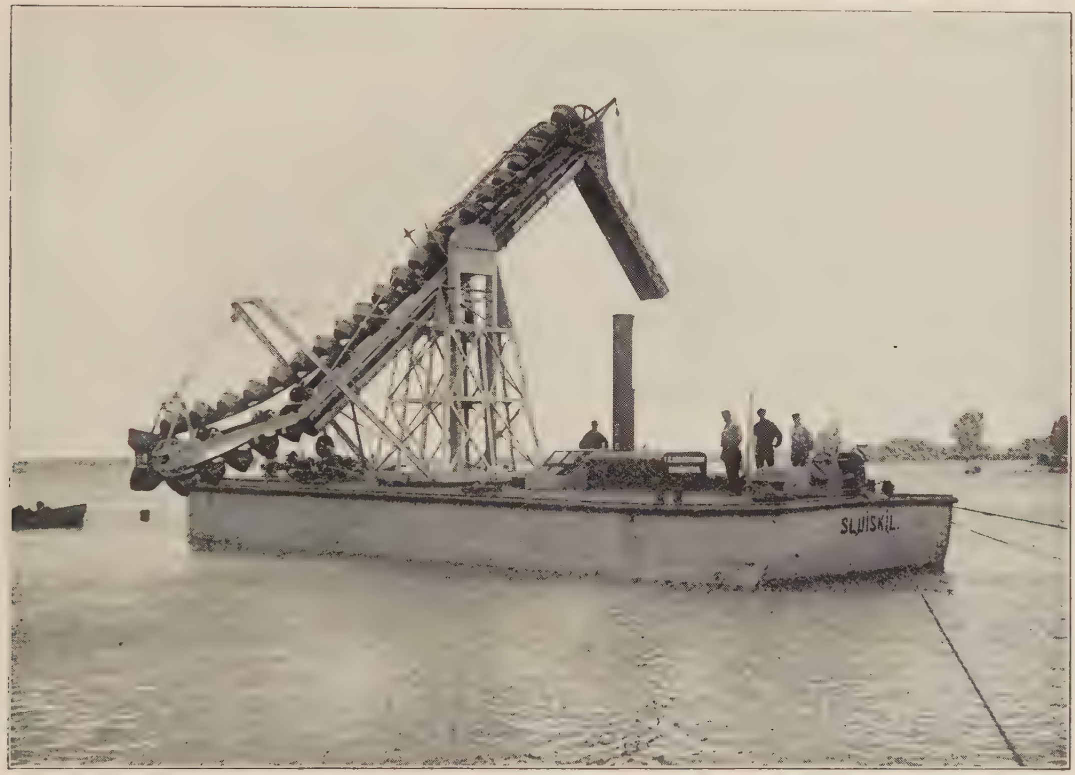


Fig. 26.

In one of the vessels there are a boiler and bunkers, as well as the main engine for driving the bucket chain, centrifugal water plant and auxiliary machinery; in the other, accommodation for the crew and storerooms are provided; the latter also carries the framework that supports the shoot.

As the latter vessel has less to carry it can be made narrower than the other.

Steam power is used for working the winch that raises the ladder, whilst brakes can be applied when it needs lowering. The ladder, which swings on a hinge, is suitably balanced by counterweight, which greatly facilitates the raising and lowering operations.

In the lower bend a guide drum has been fixed which enables the shoot to be placed in the most favourable position, and, moreover, acts as a guide for the buckets as they lift the material from the barge. This guide drum was formerly made in such a way that the outer links were supported by it; in consequence of this the buckets had to be square, which was not the most desirable shape. The latest guide drums are equipped with outriggers, over which only the intermediate links run, so that the buckets can have the desired shape, which is that of the ordinary dredger bucket.

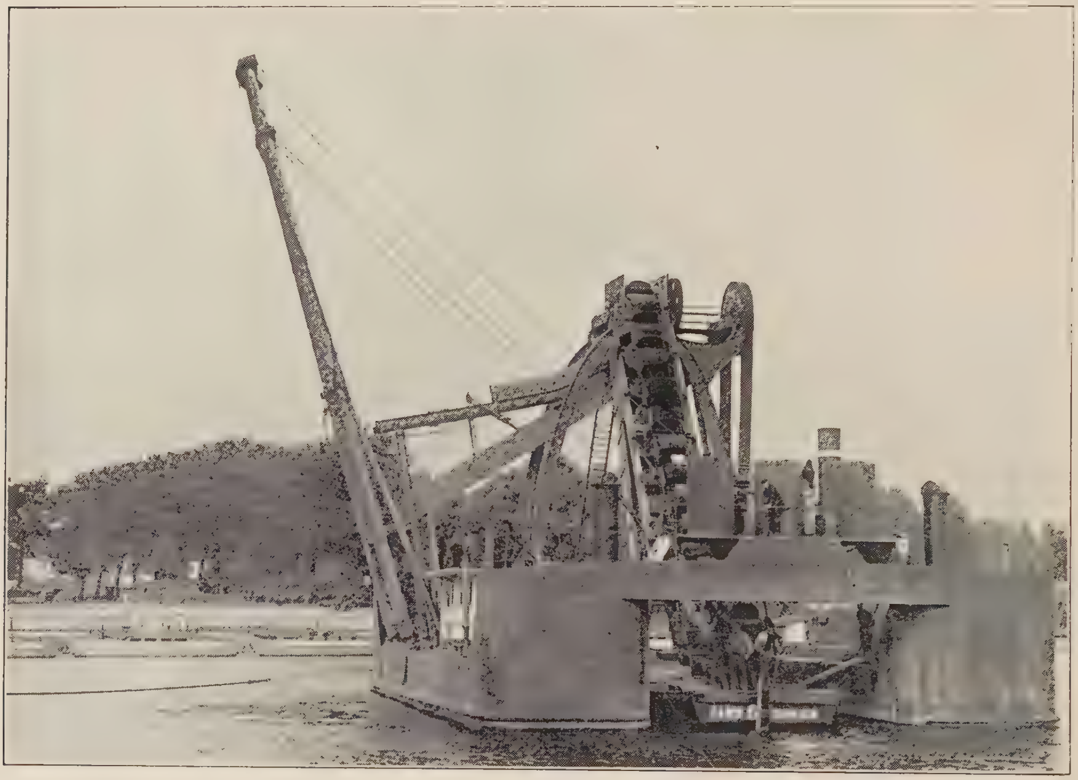


Fig. 27.

There is also a steam winch on board, on the shaft of which are two wire-rope drums. This winch serves to move the barge, while it is being emptied, towards the bucket ladder. Two steel wire ropes, attached to the barge on the starboard and port sides, are simultaneously wound on the drums.

A pump is also provided for washing the deck which dilutes the material in the barge and makes it slide more easily along the sides of the well.

The bucket chain is driven, like that of the ordinary dredger, by means of a belt, pinion and spur wheel.

In the "stationary" elevator (Fig. 28) the two ships are replaced by a pile foundation, and it functions in the same manner as the floating elevator, with this difference, that the mud is usually led through a shoot into railway trucks. With this type of elevator the jet of water is not needed.

This method was chiefly used in the construction of railway embankments, dykes, and for filling up low grounds. In both forms the elevator has done good work, and in remembrance, perhaps of their past service, the closed barges are still called "elevator barges," although the greater portion of them are no longer used for the purpose for which they were originally designed.

The capacity of the elevators has been further increased by mounting two bucket-chains side by side on one and the same ladder, constructed in such a way that opposite to each bucket of the one chain a set of intermediate links of the other chain is found (Fig. 29).

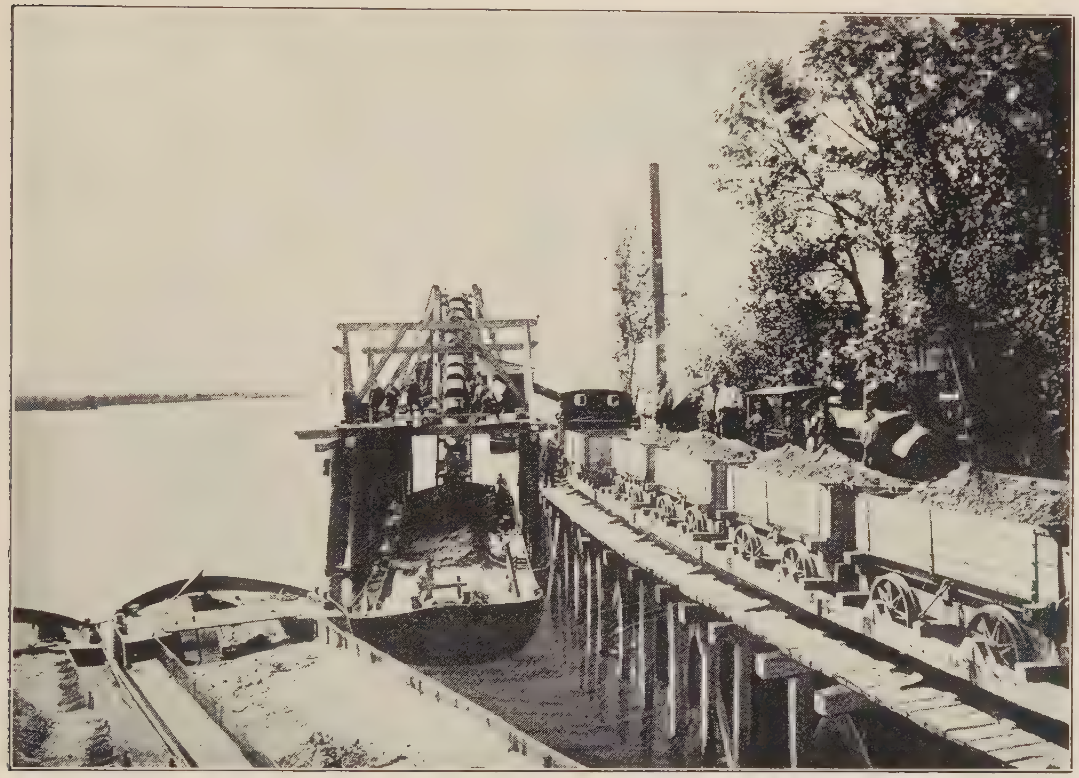


Fig. 28.

Owing to the large masses of soil that have had to be excavated of late the elevators have been largely supplanted by the modern barge-discharging suction dredger, which we shall mention again when the suction dredgers are treated.

These elevators, however, still do very good work, and by adding a conveyor they have been adapted to various purposes.

Under the shoot an endless belt has been placed about 0·90 to 1 metre wide, made of rubber, on which the dredgings, usually consisting of sand, are discharged.

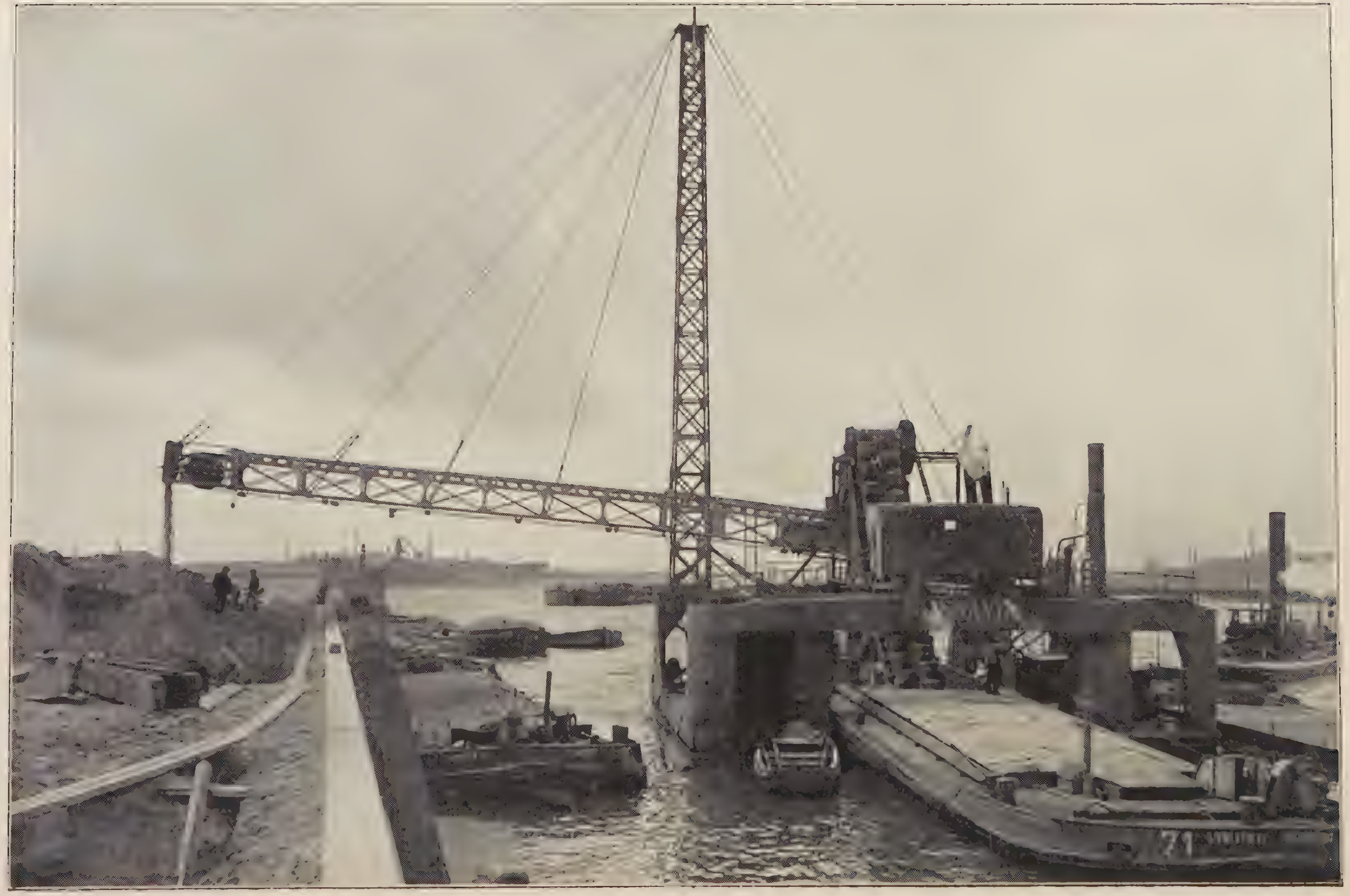


Fig. 29.

In the "stationary" elevator this endless belt is mounted on a fixed structure; whilst in the case of the "floating" elevator it hangs in a crane. The distance to which dry sand is conveyed is often considerable, frequently reaching from 40 to 60 metres.

The endless belt is driven by the main engine. The driving power required is very small when the belt inclines downwards towards the lower drum; but should circumstances require this drum being placed higher than the one under the shoot, greater driving power of course will be required. As a rule an inclination of 1 in 45 is used.

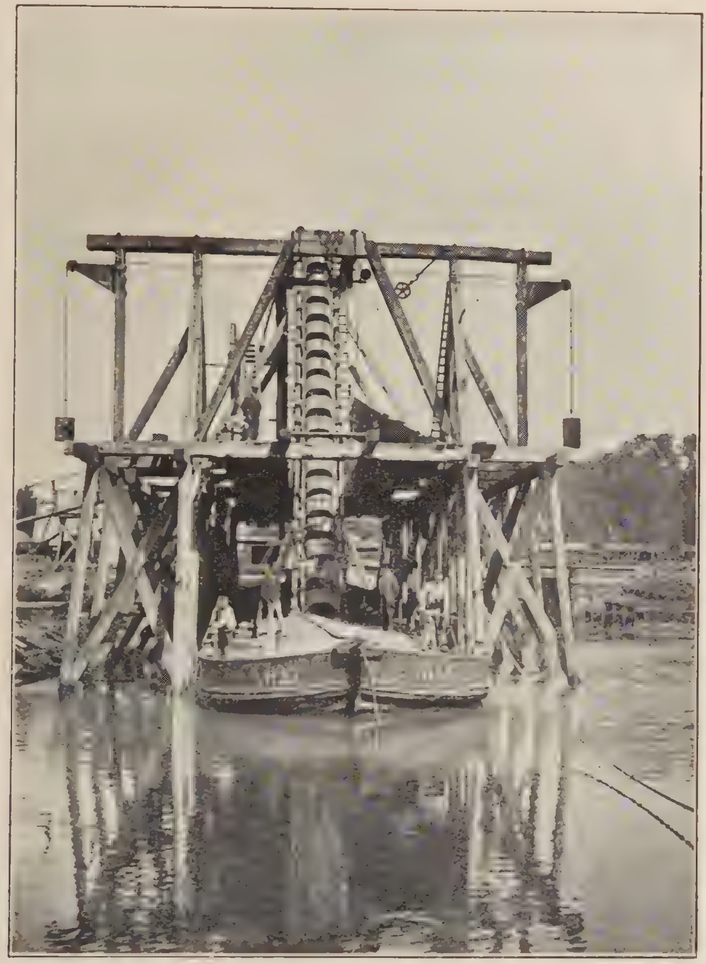


Fig 30.

It is advisable to have the distances between the guide rollers over which the belt runs as small as possible, say about half a metre, and to deposit the dredgings on it in as dry a condition as possible.

Vertical side rollers to guide the belt should be avoided because they quickly wear out the expensive belt.

With a conveyor of this kind 500,000 cubic metres of sand are often conveyed before the belt has to be renewed.

The capacity of the buckets is about 200 litres, and the daily output from 2,000 to 3,000 cubic metres.

An elevator of this kind is often used, for example, to deposit sand behind quay walls. The sand required for the railway embankment between the stations " Beurs " and " Delftsche Poort " at Rotterdam was deposited in this way ; in this case the sand had to be transported over the existing State railroad, and the trains to run underneath the conveyor (Figs. 30, 31).

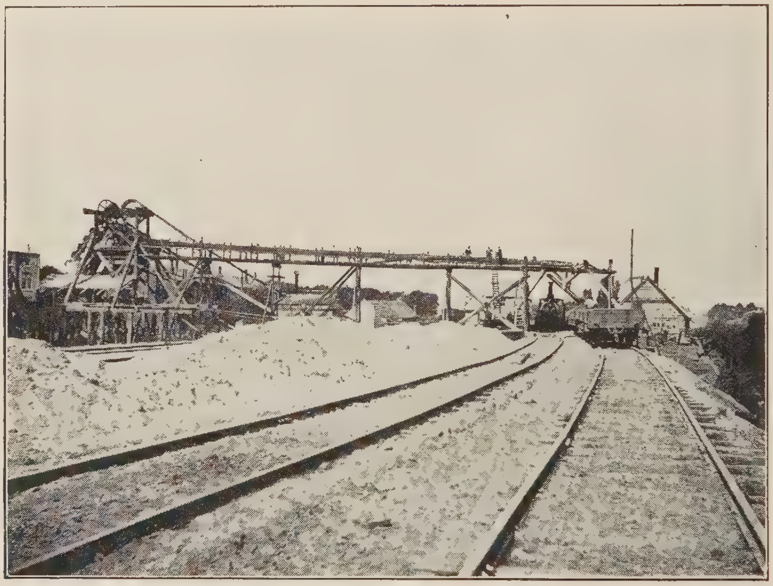


Fig. 31.

Further examples might be cited to show that the elevator, especially the last-mentioned variety, is still used at the present day.

Fig. 32 shows a rather curious specimen. The traffic takes place above the belt instead of the reverse.

Before returning to the bucket dredger it may be mentioned that at the time we speak of the first force-pump dredgers were brought into use.

About eight years later, in the year 1892, the capacity of the buckets had been increased to 450 litres, and the over-all dimensions of the vessels were approximately as follows :

Length	38 metres.
Width	6·50 metres.
Depth	3 metres.

The engine was still a horizontal compound-condensing engine of about 150 to 175 H.P. with flue boiler.

Although larger dredgers were built for use abroad, chiefly for foreign Governments, the type described above remained the largest used in Holland till about 1901. From that date, as new dredgers (Fig. 33) were built, their dimensions began to grow in size, and their bucket capacity gradually increased to nearly 600 litres; in fact, dredgers are being constructed to-day with buckets of 800 litres capacity, and several foreign Governments are using dredgers which have still larger buckets possessing capacities of upwards of 1,000 litres.

Fig. 32.

The construction of all these dredgers is the same in the main, and a detailed description of one of them is given in the following pages.

THE MODERN DREDGER (*See Appendix A*)

VESSEL

The chief dimensions of the hull of a dredger with a bucket capacity of 650 litres are approximately as follows:

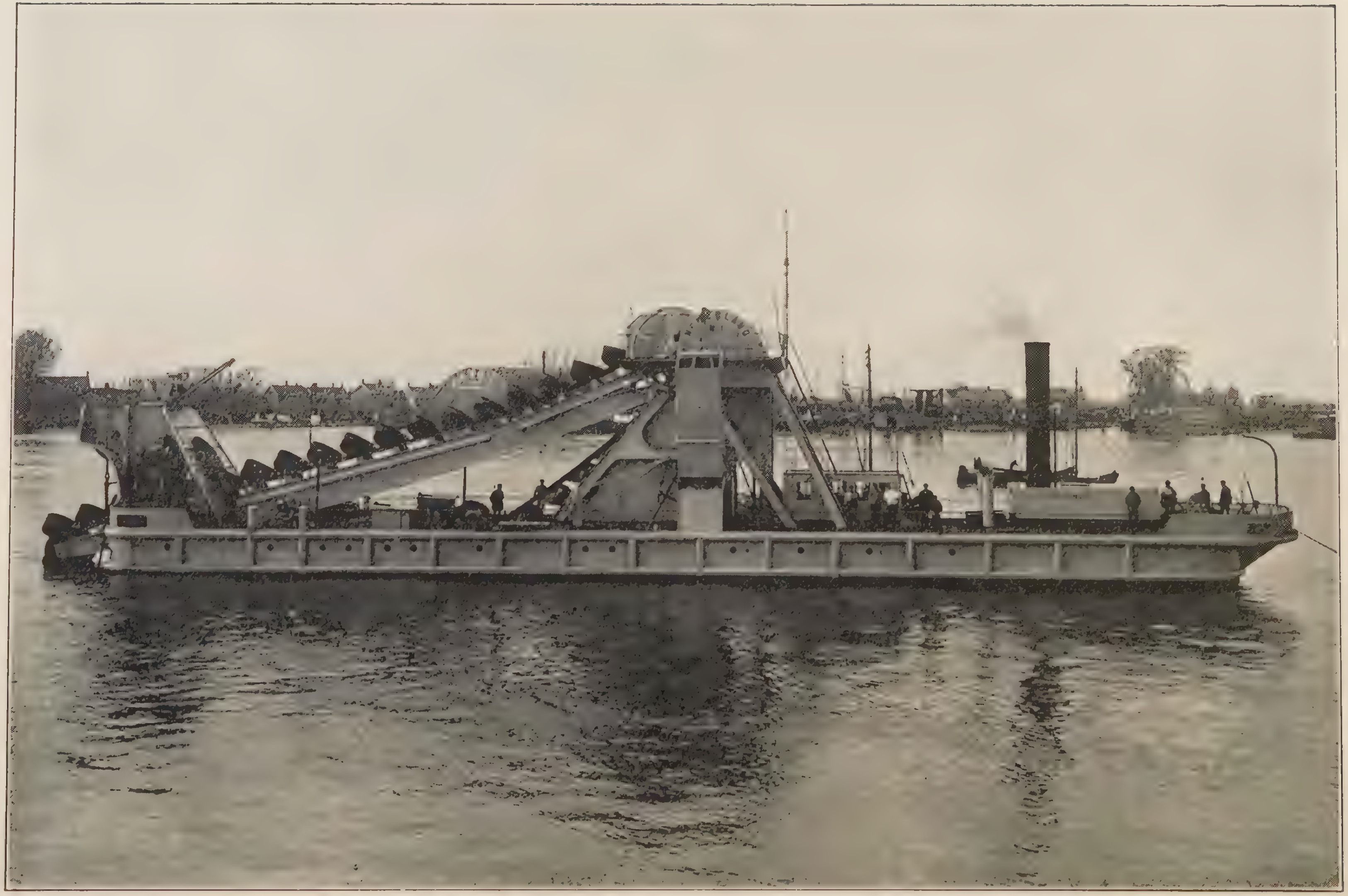


Fig. 33.

Length	47 to 50 metres.
Breadth	9 to 9·50 metres.
Depth	3·30 metres.

The vessel has a square shape with rounded corners and an open well in the middle, in which a ladder moves. The bottom rises towards the stern, and is rounded on the bow side, while the sides are vertical. Some vessels have a round bilge (Fig. 34).

The division of the ship is as follows :

1. In the forepart, on each side of the well, a watertight compartment forms a storeroom for spare parts, such as buckets, links, etc.

2. Accommodation for the overseer, dredger master and engineer, with a kitchen and a storeroom on one side of the well, and accommodation for sailors and firemen, with a kitchen on the other side.

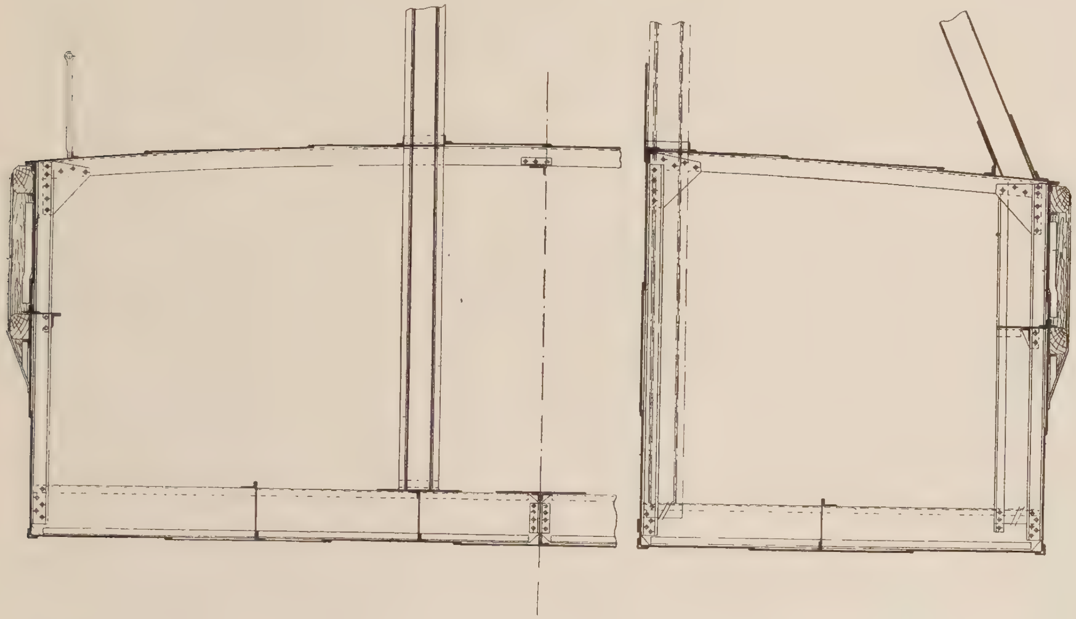


FIG. 34A.

3. Engine-room.

4. Boiler-room, with stokehold and bunkers.

5. A tank, for fresh water ballast, with baffle plates.

The entire ship is provided with two broad wales, one just above the waterline, and the other at deck level (Fig. 34A.)

On each side of the ship vertical fender beams are placed between the two wales. Under the lower wale wedge-shaped fenders are placed under every other fender beam. These prevent a loaded barge from getting jammed under the fender beam.

All the wales are broad and semi-circular, and the fenders are entirely sheathed in steel. Sometimes the wales and fenders are made entirely of steel.

On each side of the well, under the deck and above the bottom, strips are riveted which extend to the forepart of the deck, and serve to guide the bucket ladder, and at

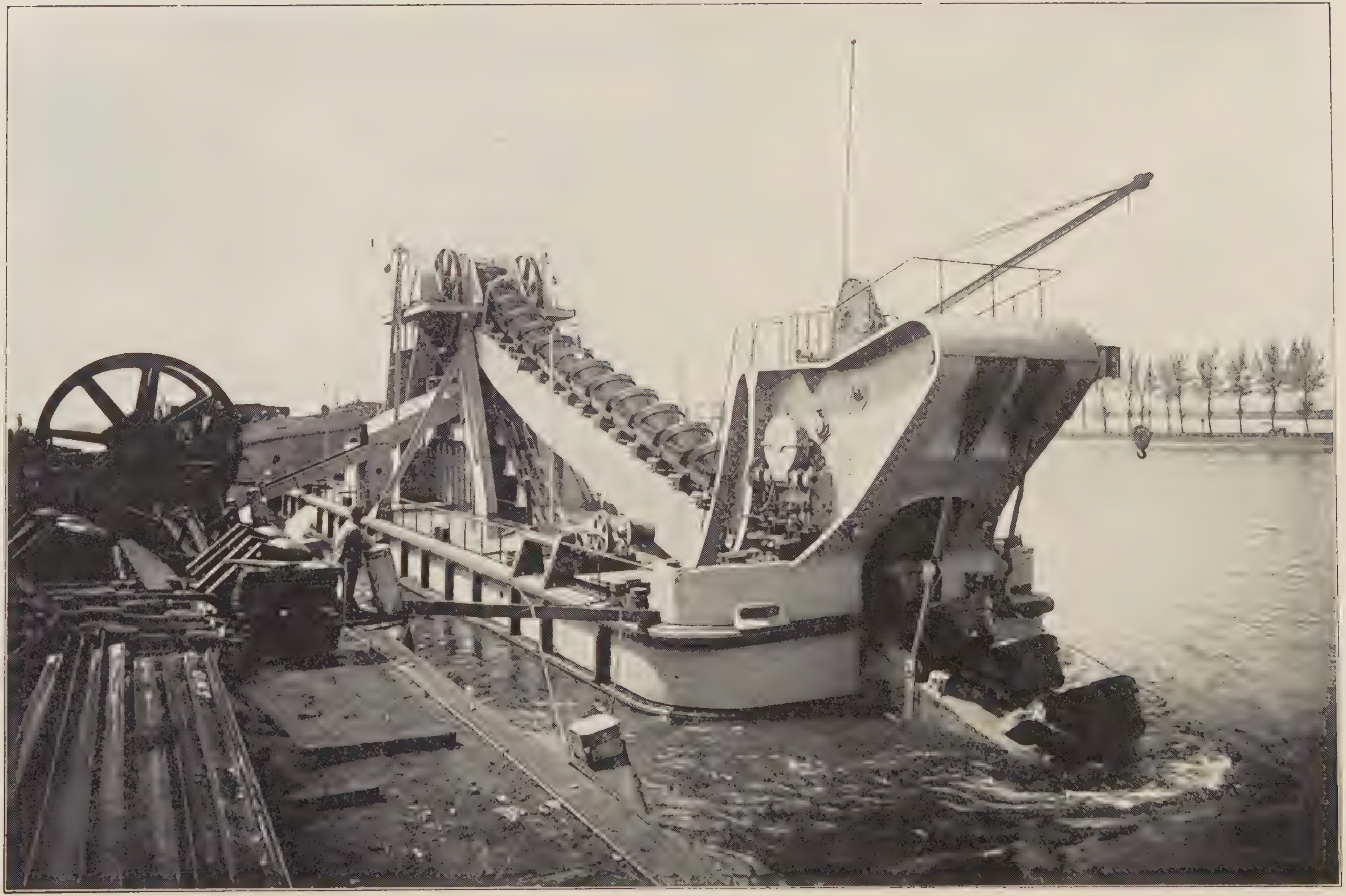


FIG. 34.

the same time to protect the well plates. The back wall of the well is protected by wood or by a double plate reaching below the waterline against the wear caused by the material dropping from the buckets.

The deck is made of smooth plates supported by strong deck beams and provided with drains and scuppers where necessary, to prevent it rusting. A fault of many dredger constructions is that the decks on either side of the well are built too lightly, no account being taken of the fact that dredged objects sometimes fall from the buckets on to the deck; heavy loads, moreover, are often placed and removed on the deck.

Fore and aft, a heavy steel-plated double bollard is found on each side of the vessel. It is advisable to make the intermediate lighter bollards likewise steel plated.

The ships are very strongly built; the frame-spacing is usually half a metre, while each frame carries a stiffening plate or bulb plate. Between the floor riders three intercostal keelsons are placed, two of which follow the sides of the ship from stem to stern, while the third runs midships up to the centre of the well.

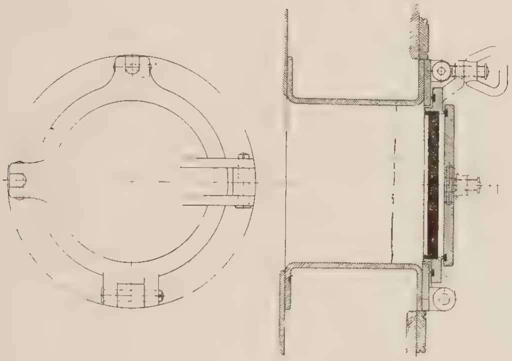


Fig. 35.

To strengthen the vessel the well-side-plating reaches down to the floor riders; besides this it is provided with a horizontal stringer plate.

Portholes with storm shutters are found on each side of the crew's quarters and engine room, and it is advisable to mount these in steel cylinders, at some distance from the outer side of the hull (see Fig. 35), to protect them from being damaged by the cork bags which have but too often to be used when moving an empty barge alongside the dredger.

At both fore and aft there is a short bulwark; at the fore end it is connected with the frame of the ladder winch, and serves at the same time to connect the sides of the well firmly.

On both sides of the ship a railing is fitted, made of wrought iron detachable stanchions, which carry an eye at the top, through which an iron pipe, about 50 millimetres in diameter, or a chain, is passed to serve as a handrail. Opposite the coal-holes this railing is collapsible, or can be easily removed.

Along the sides of the well a similar, but lighter, railing is fitted, chiefly to meet the demands of the law concerning public safety. This railing must always be removed when the lower part of the bucket chain has to be repaired or raised.

MAIN ENGINE

The engine is a horizontal or vertical compound engine of 300 I.H.P. with separate condensers. A vertical triple compound engine is also sometimes used, but many are of the opinion that for a single dredger the triple compound engine is not so economical as is generally supposed, owing to the fact that a dredger, when working, does not regularly require the power for which the engine is designed. Diagrams have clearly demonstrated this fact. For this reason the engine is always equipped with a regulator which can be adjusted to the desired speed of the bucket chain ; it is also equipped with two heavy cast-iron flywheels which at the same time serve as belt pulleys (Fig. 36).

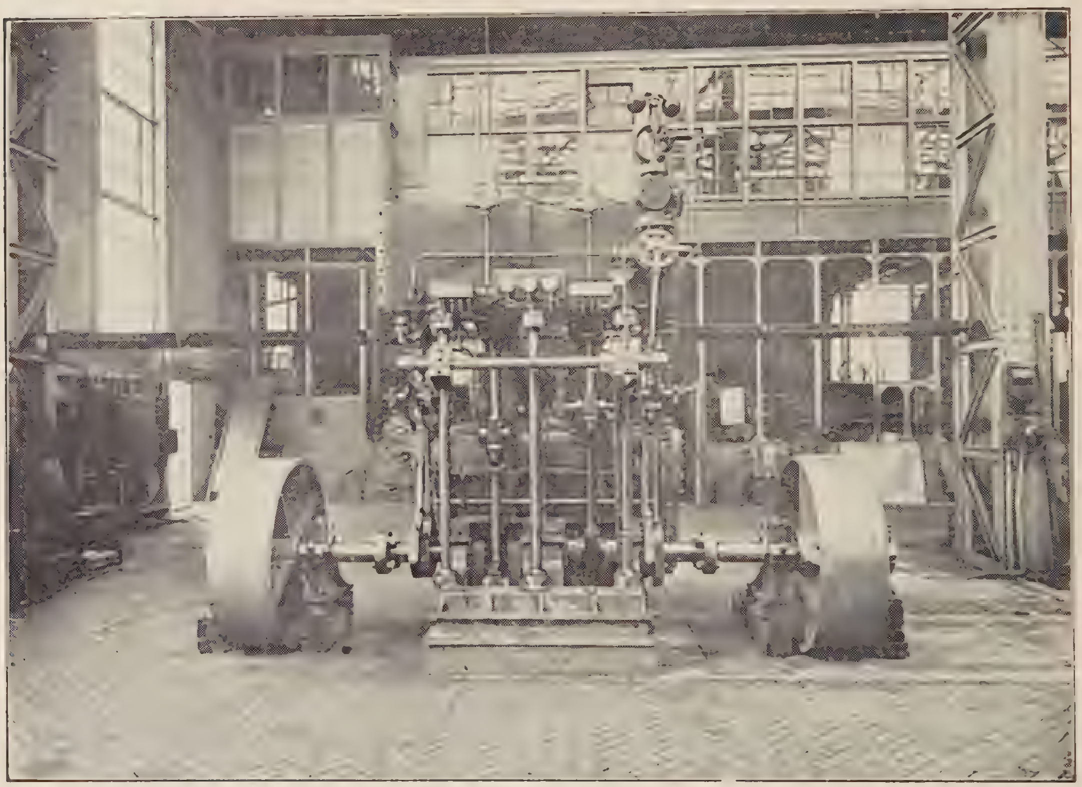


Fig. 36.

A strong hand- or steam-turning gear is provided. Steam power is advisable as it facilitates the mounting and repairing of the heavy bucket chains of these dredgers.

The place of the engine is no longer under the main framing, but more aft. This enables the driving belts, which transmit the motion to the upper-tumbler shaft, to pass above the shoot, which, again, leaves one greater freedom to place the shoot in the most advantageous position under the bucket chain to receive the spoil. With the old dredgers the shoot was placed exactly between the two driving-belt boxes, so that not only the place, but also a certain width was prescribed.

The main condenser and auxiliary condenser of the winches receive the circulating water from a direct-acting centrifugal pump, which can pump its water either from fore or aft ; if, for instance, the dredger works in a current, the clearest water is found in front of the ship, whereas when a new dredging ground is broken into, with the so-called front dredger, it will be found at the stern.

Moreover, with a seaworthy dredger which has to reach its destination under its own power, it must be possible during the voyage to pump the circulating water from the bottom of the well to prevent the pump sucking in air in consequence of the pitching and rolling of the vessel.

A vertical air pump is driven by the main engine.

Though the system described above is the most usual, yet it is clear that other methods are possible ; for example, an entirely self-working air and circulating pump of an approved system.

The condensed steam passes through an open trough into an oil filter, and is pumped from there by means of an engine-feed pump or a duplex pump to the boiler, after passing through a feed heater.

Besides the engine-feed pump and the bilge pump, there are also a duplex pump and a Giffard injector for feeding the boiler, and a duplex pump and a Giffard injector for the bilge for freeing the whole ship of water. For the latter purpose there is also a complete hand-pump plant for all compartments, which works either through simple hand pumps or through a special Dawton pump connected with the distribution boxes of the compartments.

Like the circulation water, the feeding water can be pumped either from fore or aft, and for this purpose it is connected with the above-mentioned water supply.

The suction and force pipes of these auxiliary machines are connected, as is usual, with the distribution boxes.

An ejector, or the duplex pumps, can fill the fresh-water tanks, which are connected with the distribution boxes, by means of a seacock or from a water barge moored alongside.

BOILERS

The steam for the main and auxiliary engines is supplied by one or two boilers of the ordinary marine type of the requisite capacity.

It is important that the funnel should be higher than the main framing to get a better draught ; it should also be provided with a damper to regulate the latter. The boilers should be fixed like those of a sea-going ship, to prevent rolling, in case the dredger has to cross the ocean.

A passage should be kept free between the bunkers and the sides of the ship to prevent the latter rusting.

SHOOT WASHING

When sand, or dry, or stiff material is dredged, it is necessary to wash this material into the barges by means of a jet of water which is poured into the top of the shoot.

For this purpose a direct-driven centrifugal pump, with a delivery pipe, 20 centimetres in diameter, is placed in the engine room ; the water is drawn from under the bottom and pumped to the required height.

The dredger master can regulate the water supply to the shoot from his place at the ladder winch by means of a stop valve.

This centrifugal pump can serve at the same time as a salvage pump by inserting a T-piece with a second regulator in the suction pipe ; this suction pipe ends between the floor riders.

ELECTRIC LIGHT

A direct-driven dynamo is placed in the engine room, which supplies current for :

1. Three arc lamps of 1,000 candle power each, fitted with plug contact and hoisting gear. One is placed near the ladder winch at the fore part of the well, and the other two on the platform of the main framing in such a way that they light the nearest barges and the stern of the vessel.

2. All the incandescent lamps for lighting the engine room, stokehold, crew's quarters, store-rooms and water closets, as well as the lamps near the various winches, and a powerful lamp with a special glass cover on the fore part near the ladder winch to light the tumbler.

3. Some hand lamps, which can be attached to plug connections in the stokehold, engine room, store rooms, and on the deck.

DREDGING INSTALLATION

MAIN FRAMING

The framing for the dredging installation, which is usually called the " main framing," consists of two trestles with cross-beams, built of box girders composed of steel plates and angles erected at the back of the well.

The front legs of the yokes extend to the floor riders, and are built against the sides of the well, while the back legs either reach vertically to the top end of the floor riders or are supported by a box girder, or bridge, underneath the deck ; often the legs of the framing are constructed in such a way that the framing can be easily removed, either partly or entirely, which may be necessary at times to enable them to pass through fixed bridges (Fig. 37).

At the top the yokes are joined by a platform on which the gearing of the ladder is placed. This platform projects on either side so that it enables one to pass on the outside of the belt boxes. From the deck this platform is reached by a convenient staircase with a hand rail, which extends to the front side of the platform.

The sloping front legs of the main framing are constructed in such a way that the steel ladder supports of the bucket-ladder shaft, which are supported by them, can easily be lowered in order to dredge at greater depths.

The main framing is supported on either side by a prop, or stay, which reaches from the sides of the ship to about the height of the ladder supports.

The framing is covered on all sides by steel plates, and a door on the deck gives admission to the bucket ladder. This is necessary when the latter has to be repaired, which is done on the lower part of the ladder.

At the place where the buckets pass the tumbler a mudguard protects the platform.

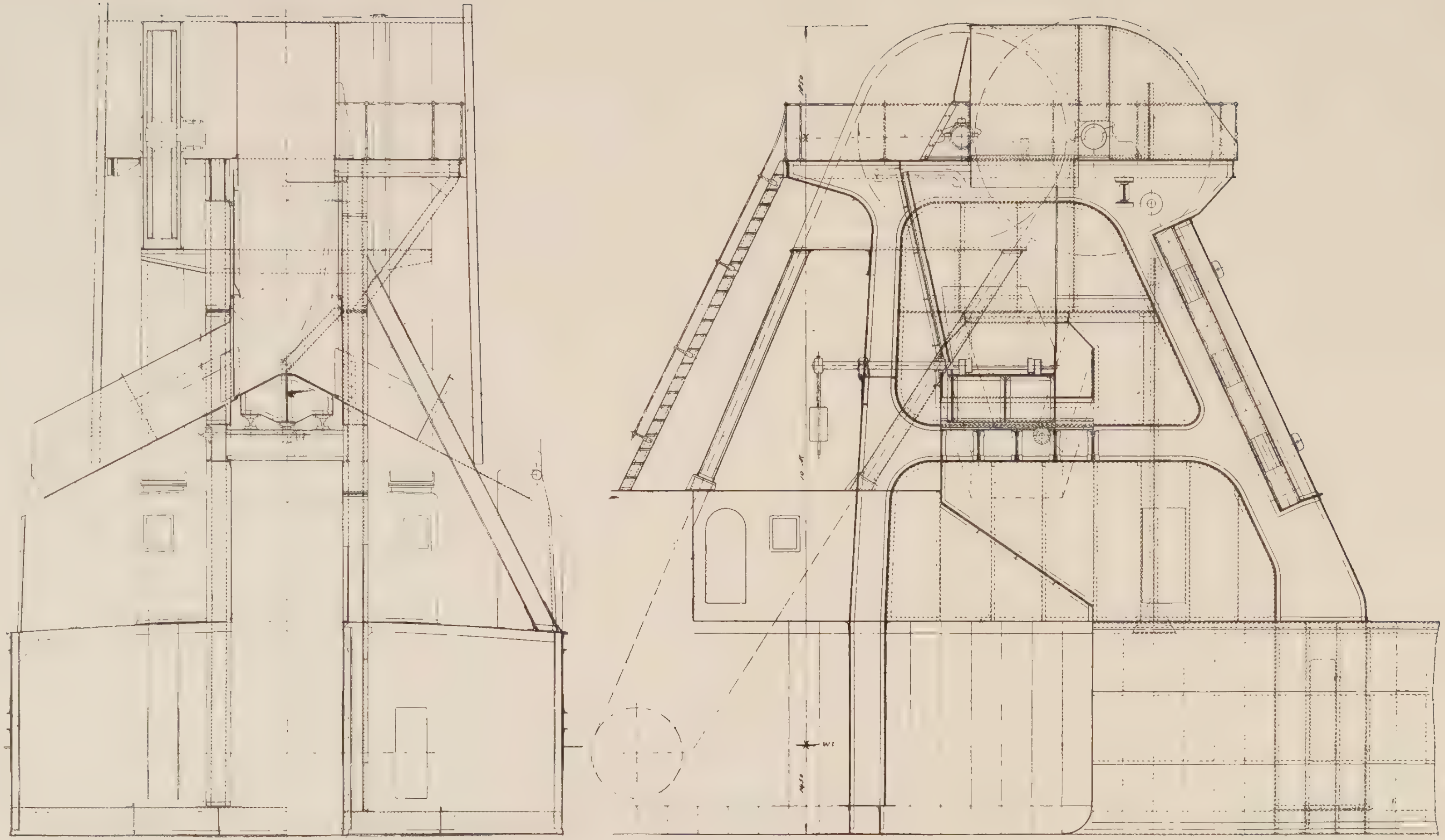


FIG. 37.

If the tumbler has to be repaired or replaced, the mudguard must first be removed, for which purpose it is made detachable.

On the platform there are, further, a signal mast for hoisting signals ; for example, three black balls or lanterns for high-sea navigation, and two flagstaffs pointing to starboard and port for the signals which indicate the side on which vessels must pass the dredger.

SHOOTS

Between the two yokes of the main framing there are two cross-beams, over which the middle part of the shoot can be made to slide sidewise in a longitudinal direction in respect to the vessel. This is done so that the shoot can be moved in the most desirable position under the bucket ladder to receive the spoil. In this way the inevitable waste of spoil is restricted as much as possible.

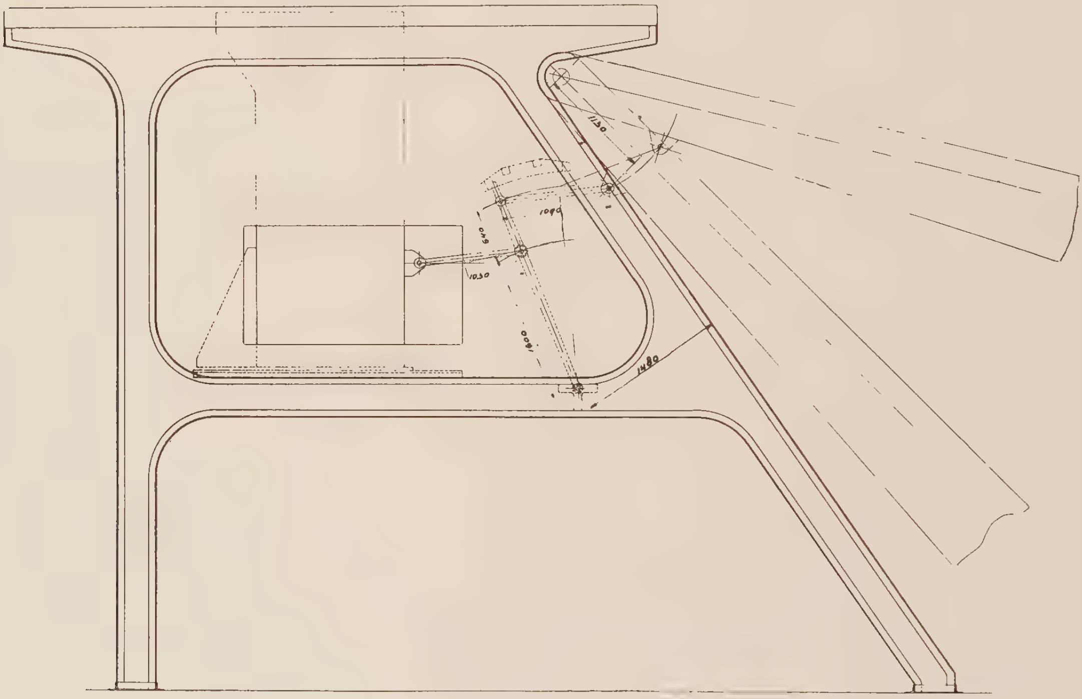


Fig. 38.

The shoot, which is connected by suitable means to the bucket ladder, moves automatically according to the position of the latter. When the ladder is lowered to enable dredging operations to be carried on at greater depths, the shoot is caused to move backward, and when the ladder is raised, to move in a forward direction (*vide* Fig. 38). It is, moreover, possible to move it by hand by means of a pinion and rack ; this is useful in case the automatic adjustment should break down. When dredging at fixed depths in stagnant water the shoot can be adjusted by means of the hand mechanism to the most advantageous position.

In the centre of the shoot there is a door, or movable partition, which enables the spoil to be diverted to either the starboard or port side as may be desired. This door is very heavily constructed similarly to that of the rudder of a sea-going ship. This is necessary as it has to withstand the continual impact of 650 litres of spoil, more or less, frequently admixed with a large number of stones, the effects of which must not be underrated. The shaft on which this door is fixed extends some distance behind the main framing, and carries a counterweight, so that the door can be opened by hand, which must, moreover, be possible without interrupting the dredging operations. With regard to the construction of the shoot, it should be remembered that this door ought to be easily renewable. With very large dredgers this door is moved by steam power.

Against the side plates, and supported by a cross-beam, the fixed shoots are placed on either side. These are made wide enough to give the movable part of the shoot, which opens into them, sufficient room to move sidewise as the position of the bucket ladder is altered.

The fixed shoots are covered on the top as a protection against splashing water. At their extreme ends they are supported by consoles, inside of which, on the one side of the ship, are placed the W.C.'s, and on the other side the store places for lamps.

Cranes, called "shoot cranes," are built against the fixed shoots both on the starboard and port sides. These cranes rise above the mudguard on the platform of the main framing, and to strengthen them they are firmly connected with that framing. At the same time they support the protruding part of the platform. To strengthen them still more, the top ends of the shoot cranes are firmly connected together.

On these cranes the movable shoots are suspended ; they are connected with the fixed shoots by means of hinges, and finally convey the spoil to the nearest barges.

The fixed and movable shoots are constructed in such a way that the latter, when hoisted, do not protrude beyond the outer side of the wales ; this is done to protect them from damage when passing through bridges and locks or by barges coming alongside.

All shoots are equipped with a double bottom plate to protect them against wear ; the angle of gradient is about 30 degrees.

Though the shoots are usually placed at right angles to the longitudinal axis of the vessel, sometimes they are placed edgewise towards the stern as this position facilitates the loading of very large barges. At the same time it lessens the splashing, because the spoil is delivered in an oblique direction against the hold sides of the barge. A drawback to this method of construction is that it is more expensive, and the wear of the front parts of the shoots is somewhat greater.

BUCKET LADDER

The bucket ladder is generally built of steel plates and angles. It consists of two wing plates of sufficient height which are firmly connected by means of cross-beams and transoms. With the latest dredgers the longitudinal angle irons of the wing plates have been replaced by U-irons on the inside at top and bottom (*vide* Fig. 39). Although this construction is widely used, it is perfectly clear that many variations are possible, provided the bucket ladder is constructed strongly enough to resist the many shocks and knocks of the lateral pressure exercised upon it.

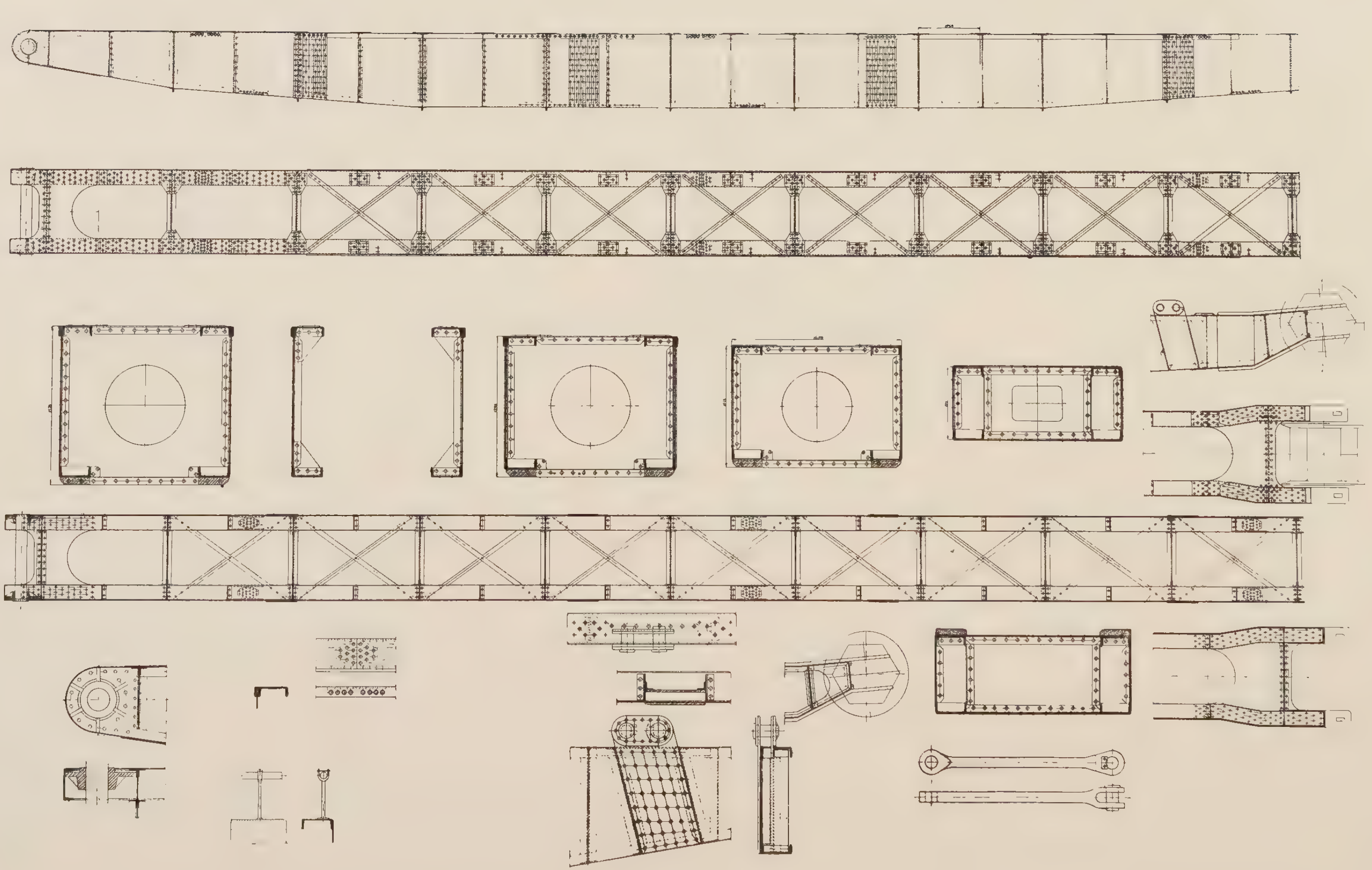


Fig. 39.

The top end of the ladder is suspended by a heavy shaft which is supported by cast steel bearings fixed to the sloping legs of the main framing. The shaft should be heavy because of the many shocks it has to undergo, for example, when dredging in a broad fairway with a heavy swell, or when wrecks, stones, etc., are encountered. For the same reason there should not be any space between the bearings of the ladder, nor between those of the crane legs. The lower part of the ladder particularly requires special attention, for it is here that the tumbler is placed between the two side girders. If the construction is not very strong these will very soon give way towards the outside. This tendency is caused not only by the incessant pressure exercised by the dredging operations, but becomes more acute still if the buckets should inadvertently catch any steel wire, chain, etc., and cause them to become wound between the tumbler and side girders.

For this reason the last cross-beam should be placed as near as possible to the bottom tumbler, at the same time taking care that there is sufficient clearance between the tumbler flanges and the cross-beam to prevent their coming in contact with each other as the bearings wear out.

It is advisable to place the last but one cross-beam at the most not more than 1½ metres from the last; the others may be placed at intermediate distances of 2 to 2½ metres.

At the end of the side girders there are heavy wrought or cast steel beams which, for strengthening purposes, extend to the second cross-beam, and which carry the bearings in which the journals of the tumbler revolve.

The lower part of the ladder is suspended in two places from two heavy plates riveted to the side girders. One of these serves to suspend the ladder, while the safety cable is attached to the other. This cable runs over the ladder and is guided by wrought-iron saddles.

These cables should always be in working order when the dredger is operating in a place where it might be necessary to lift the ladder as quickly as possible to prevent further damage in the event of the ladder wires giving way. But where these precautions are not necessary it is better to keep these expensive cables in the store room, lest they should become unreliable by reason of their long exposure to the elements, and to call in the help of a diver to attach the cables to the eyes when the need arises.

The outsides of the ladder girders carry flat strips, which slide along similar strips attached to the sides of the wells, with no more clearance than is necessary to move the ladder easily up and down in the well.

The upper sides of the girders carry the frames in which the ladder rollers turn, and which guide the bucket chain towards the upper tumbler (Fig. 40). These guide rollers are made of chilled cast-iron or manganese steel, and are forced hydraulically on to the shafts.

Chilled iron rollers are to be least recommended as they easily split when forcing them on the shaft, or break when in use, owing to the continual pounding of the bucket chain. The ends of the shafts are provided with shrunk-on steel bushes which revolve in easily renewable cast-iron bearings fitted into the frames of the guide rollers, and are lubricated with heavy grease. These frames are closed on the outsides so that the grease is pressed towards the insides, whilst sand and mud are, at the same time, prevented from entering.

The guide-roller frames should be mounted on an oaken filling piece, and an extra plate should be riveted on to the ladder to protect it from being damaged in case the bearings should get loose.

The bearings are mounted one pair on and one pair between each cross-beam. Thus, only the latter require extra supports, and by this arrangement a fair number of rollers is obtained. With an intermediate distance of two metres between the cross-beams, the distance between the rollers becomes consequently one metre, and although this distance is shorter than is usual, it may be looked upon as an improvement. For it must not be forgotten that the weight of the present-day bucket chains, when the buckets are full, is considerable, and that the rollers have to resist heavy blows when unusual resistance is met with at the moment when the upper tumbler slips through the bucket chain.

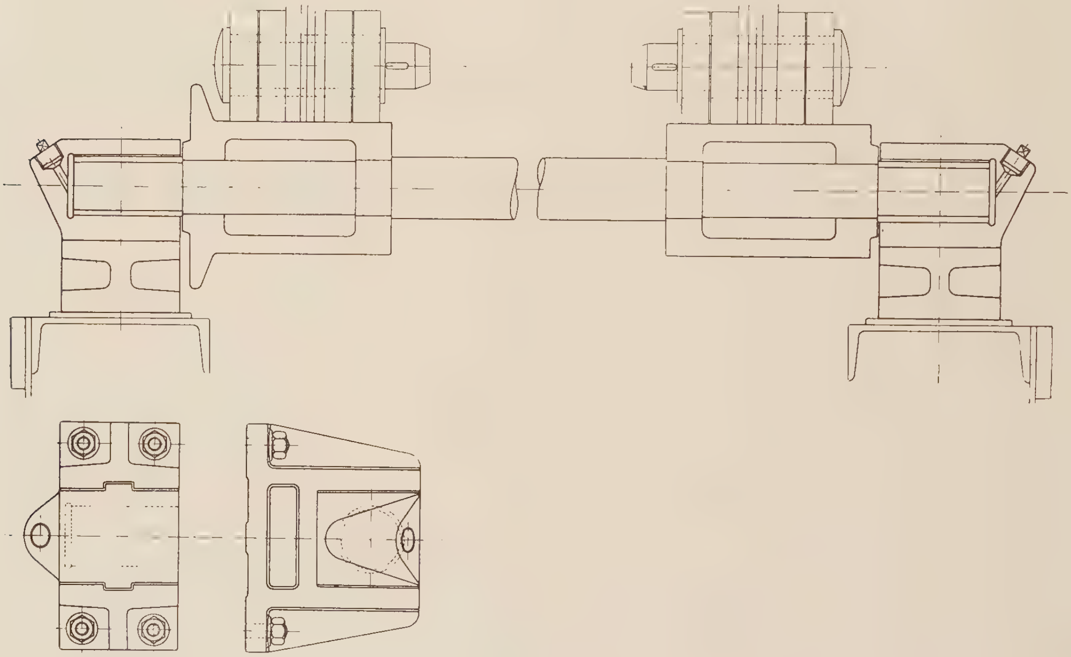


Fig. 40.

All the guide rollers have flanges cast on the outsides ; this is really not necessary, as it suffices if only a few are so equipped.

The part of the ladder above the deck is sometimes provided with mudguards on either side of the buckets. Government dredgers are usually thus equipped, while contractors' dredgers, as a rule, do without them ; the latter do not consider it an advantage because these mudguards catch much wind and, moreover, make the replacing of the rollers very difficult. The underside of the ladder is closed at the top by a plate to convey the spilled water and mud back into the well.

The length of the ladder naturally depends on the desired dredging depth. In some dredgers the ladder is made long enough to reach to from 14 to 16 metres below the level of the water. If we take into consideration the fact, which has already been mentioned in the description of the main framing, that the bucket-ladder shaft can be lowered along the foremost sheers, sometimes even as far down as the deck, the very considerable depth of 20 metres can be obtained. In a few special cases even this depth has been exceeded by several metres, as, for example, when a mooring place had to be dredged for a floating dry-dock.

Fig. 41 shows how with every dredger a greater depth may be reached. An extra long ladder, which reaches to the desired depth, is substituted for the usual one, and on the top of the ladder winch an auxiliary crane is placed, moored to the main crane. The ladder winches can thus be led in the best way to the points where the ladder is suspended.

The ordinary depth that is dredged by sea-going vessels is now about 12 metres. Adding a few metres for losses and difference of tide levels, a depth of 14 metres may at present be considered as normal.

AUXILIARY LADDER

In order to guide the bucket chain in the best possible way towards the tumbler, it would, theoretically, be preferable if the tumbler shaft and the ladder shaft could always occupy the same relative positions irrespective of the position of the ladder, as was originally the case. However, the construction proved practically unworkable owing to the continual necessity of renewing the worn-out tumbler, and consequently the ladder was suspended by a separate shaft.

By placing the ladder-shaft bearings on the crane legs, and owing to it being necessary to lower the ladder to reach a greater depth, the guiding of the bucket chain over the rollers at the top end became insufficient, so that an auxiliary ladder was resorted to. This auxiliary ladder has an independent shaft of its own, as near as possible to the tumbler, the other end being supported by the bucket ladder. Several guide rollers are mounted on this auxiliary ladder.

The auxiliary ladder renders excellent service, especially when the main ladder is lowered, and its construction is such that, no matter in what position the ladder may be, the auxiliary ladder will support and efficiently guide the chain to the tumbler.

If desired, the auxiliary ladder may be also equipped with mudgards.

TUMBLERS

Though the English usually speak of " top " and " bottom " tumblers, in Holland they are generally called the " square " or " pentagonal," or " hexagonal " tumbler according to their shape. Every expert will at once understand that the former must be looked for at the top of the main framing, and the latter at the bottom of the ladder.

Though the bucket chain moves round both, it must not be forgotten that the former transmits the power of the engine to the bucket chain, while the latter may be looked upon as a roller round which the chain is guided back. Thus it is clear that the two tumblers work under very different conditions.

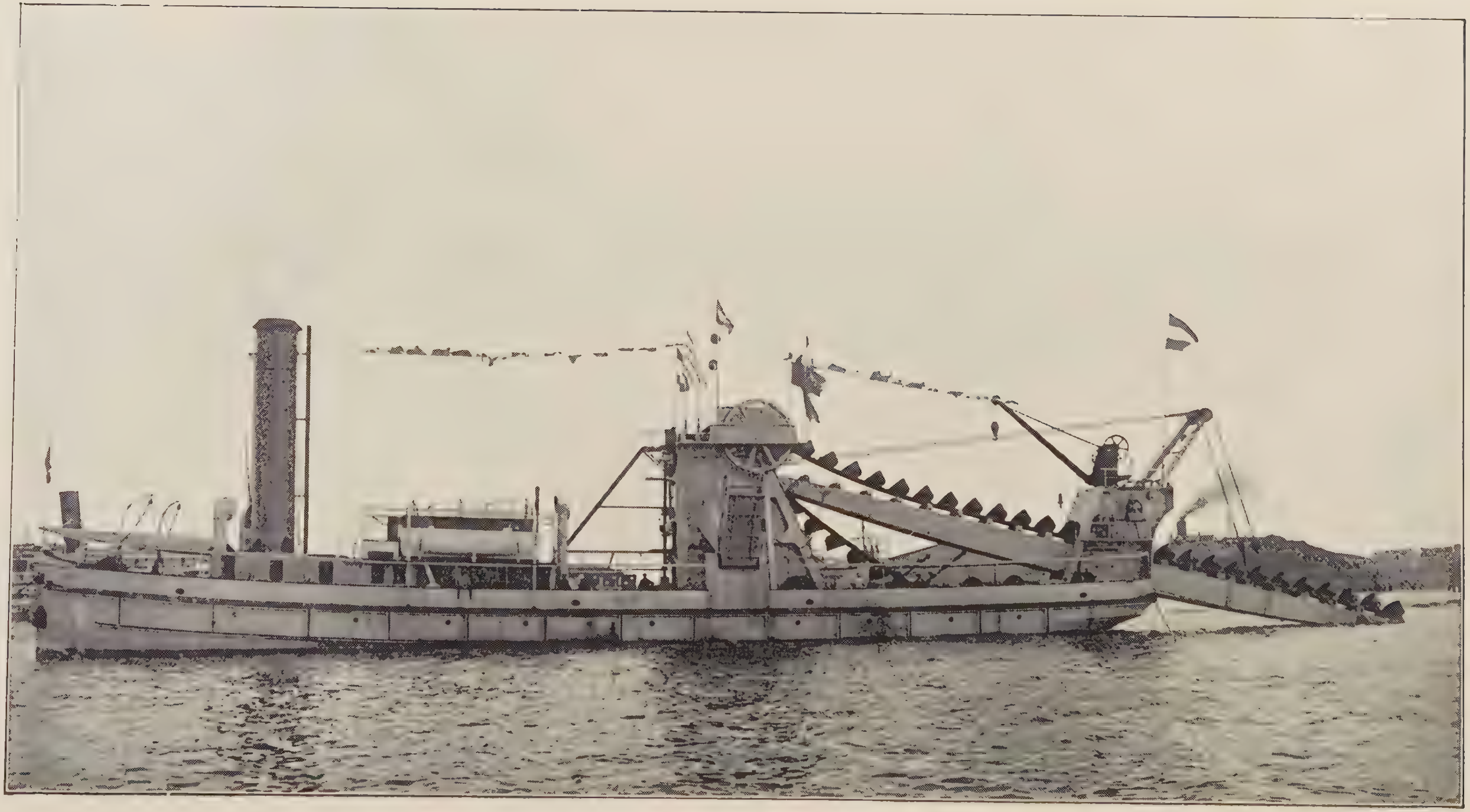


Fig. 41.

Long experience with all types of tumblers has shown that with very heavy bucket chains it is advisable to use a solid casting of the hardest and toughest quality material instead of the old form, which consisted of one or two castings fitted with renewable corners, or wear pieces, in those places where they wear out most. For it has been proved that the buckets, on reaching the tumblers, strike them with such force that neither rivets nor bolts and nuts are proof against it, and get loose within a few days.

BOTTOM TUMBLER (HEXAGONAL TUMBLER)

Taking into consideration that the bottom tumbler serves as a guide roller, the most preferable shape would be the circular one, and the construction that comes nearest to this is certainly the best; hence a hexagonal tumbler is better than a pentagonal one in that place. Greater wear of the bucket pins and bushes is caused when the angle is small between two sides, and the only reason why yet more sides are not given to this tumbler is that its circumference would become too large.

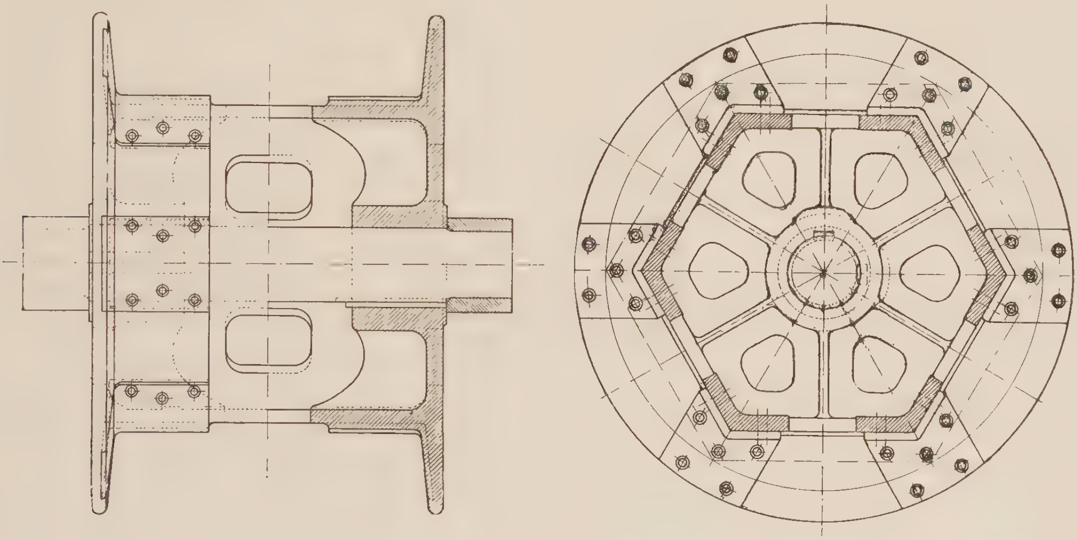


Fig. 42.

When the buckets are not larger than 500 litres, a tumbler with renewable corner pieces is often preferred (*vide* Fig. 42). The body is made of cast steel and the corner pieces of special manganese steel. These corner pieces carry a cast-on flange in the exact spot where the head of the bucket rivet hits the flange. The result is that this wearing point is renewed simultaneously with the corners, and the flange allows the corner pieces to be secured with more rivets.

With larger dredgers a solid tumbler is preferred, as the lower cost of renewing the corners does not counterbalance the risk of breakdowns through their working loose.

In a few special cases a cast-steel lower tumbler is used. The worn places can always be filled again by means of the latest methods of welding.

Cast iron in the form of chilled iron is also used, but the drawback is that the flanges break too easily when hard objects get jammed between the bucket and the flange.

To meet this difficulty a special kind of manganese steel has lately been used successfully. This is the " Era " manganese steel invented by Sir Robert Hadfield, Bt., a steel which combines the properties of glass and lead, or, in other words, possesses the combined properties of extreme hardness and great toughness. It can only be machined by grinding, and has proved an excellent material for tumblers and other components of dredgers.

The tumbler is keyed on a shaft, the two journals of which are fitted with shrunk-on ladder. Although these are closed on the outside they are nevertheless subject to great wear and tear caused by the sand getting in. Improvements in this respect are still looked for ; water-flushing on the bearings is to be recommended for example. In any case it is necessary to use long and heavy journals in order to make the wearing surface as large as possible.

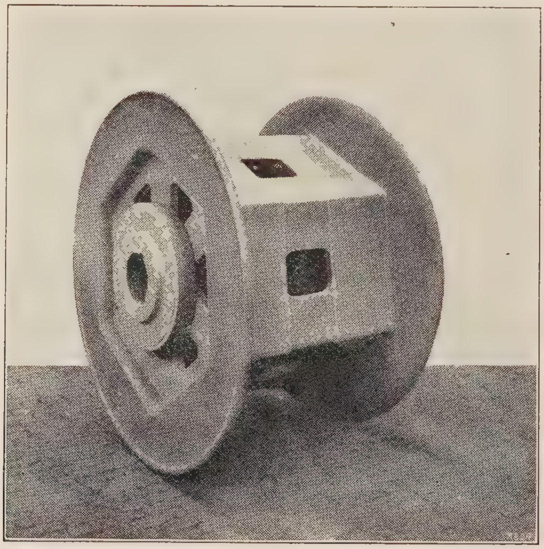


FIG. 43.

The bearings must be constructed in such a way that they can be replaced without removing the tumbler. This is possible when the bearings have no flanges on the inside but are kept in their proper places by means of a stud at the end of the ladder. When the bearings have to be renewed jack-screws are placed between the tumbler and the cross-beam, which push the former away so far that the bearings are freed of the stud, and can be removed to the outside without any difficulty.

The bearings may either be made in a single piece or in two halves ; but it is of the utmost importance that in the wearing places the material should be of sufficient thickness, *i.e.*, at least one decimetre.

Experiments have been made wherein the tumbler was allowed to revolve round its shaft, but up to now results have not been satisfactory. Further trials in this direction should be made, however, as it would be an advantage to have a fixed shaft, inasmuch as it would reinforce the ends of the ladder.

Whatever design is adopted for the tumbler, it is imperative that the edges between two tumbler sides should extend the entire length of the tumbler, as it happens occasionally that the bucket chain runs off the tumbler, and it is clear that it would be very difficult to replace it in its normal position if these edges were interrupted.

QUADRANGULAR OR PENTAGONAL TUMBLER (TOP TUMBLER)

This tumbler may have four or five sides, and is, consequently, called a " quadrangular " or a " pentagonal " tumbler as the case may be. Formerly a square shape was generally preferred, but gradually the pentagonal tumbler has gained the ascendancy.

As has already been stated, the bucket chain is driven by the upper tumbler. When unusual resistance is met with it sometimes happens that the chain slips over the tumbler, and for a long time it was asserted that this occurred more readily with a pentagonal than with a quadrangular tumbler. This theory, however, has been proved to be erroneous, and it is more likely that the opposite is true ; for, as a rule, the quadrangular tumbler is gripped by only two links, while the pentagonal tumbler is always gripped by three ; so that with the former only one edge needs to slip, whereas with the latter two would have to slip simultaneously.

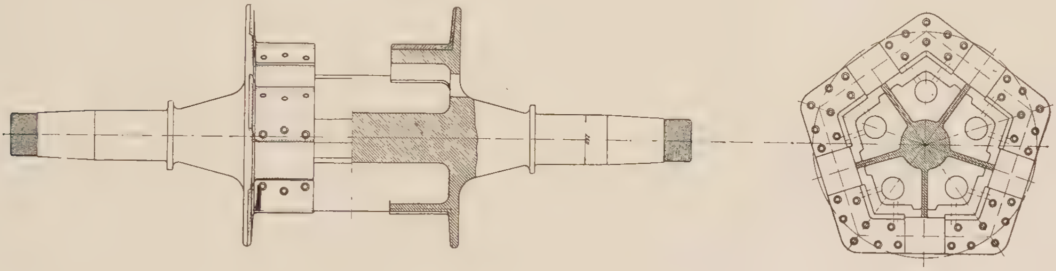


FIG. 44.

As soon as it had been proved that the pentagonal tumbler moved the bucket chain under the most difficult conditions just as well as the square tumbler, the following advantages led to the adoption of the former as the standard one.

In the first place the bucket chain mounts and leaves the pentagonal tumbler more smoothly than from the square one in proportion to the difference between the heights of the two segments.

Not only is there less impact on a tumbler of this form, but it also results in less wear and tear of pins and bushes, which are also diminished by reason of the more obtuse angle.

Another advantage is that the pentagonal tumbler wears less quickly than the square one, because it has one face more. The weight of the bucket chain is consequently borne by more faces than one ; but, what is still more important, bucket and intermediate link are alternately supported by each face owing to the uneven number of the latter, so that these faces wear out more regularly over a much greater surface.

As a last advantage the bucket does not pass a pentagonal tumbler so quickly as a square one, hence the bucket has more time to discharge its contents into the shoot, which results in less spilling.

The tumbler should be very carefully fixed to the shaft, as it happens too often that the incessant blows of the filled buckets cause it to work loose. The shaft should either be forced into the tumbler under hydraulic pressure, or the tumbler should be heated and shrunk on to the shaft. The keys also should be well secured to prevent them working loose.

To meet these difficulties, the tumbler and shaft are sometimes made in one piece of solid cast steel.

When a tumbler has to be changed the lower part of the bucket chain must be taken to pieces, which means much labour and time. This involves great losses if it should have to be done unexpectedly, because in that case the work has of necessity to be interrupted and the dredger and all vessels dependent on it to lie idle. Thus it is clear that with respect to the tumblers, not the cheapest, but the most durable materials are to be preferred if the utmost economy is desired.

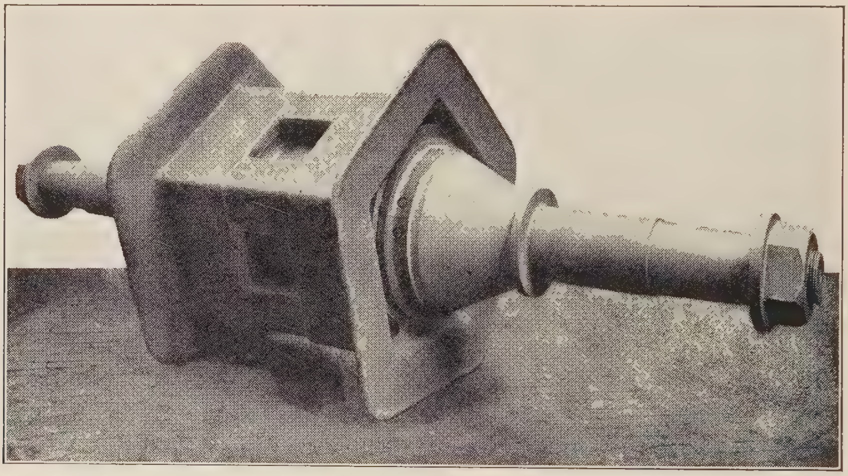


Fig. 45.

As regards the construction the following examples are given as being the most preferable. It may be mentioned here that, unlike the lower tumbler, it is not necessary that the upper tumbler should extend over its whole width.

As in the case of the lower tumbler we find, for a bucket-capacity up to 500 litres, a cast-steel pentagonal tumbler with renewable manganese corner pieces is the usual practice. Fig. 44 gives an example where the tumbler and shaft are cast in one piece.

With buckets of a larger capacity a tumbler of cast-steel, or chilled iron, is used ; the latter frequently being preferred because the wearing surfaces are much harder, and consequently more durable. Round the two hubs there are heavy rings shrunk on, which is done because of the heavy keying-on of the tumbler to the shaft.

Pentagonal tumblers of " Era " manganese steel are also largely used ; Figs. 45 and 46 show the latest methods of construction of these. The outer mantle, comprising the tumbler and the flanges, is firmly secured on both sides to a heavy cast-steel shaft by means of two keys. The working loose of the keys is rendered impossible by means of two half-rings, A, which are bolted in the two grooves, B, while a shrunk-on ring is placed round the two half-rings; thus they serve at the same time to prevent the tumbler from moving along the shaft. Not only is the tumbler of exceedingly hard and tough steel, but with this construction only the outer mantle needs to be renewed when worn out.

The shaft, in particular, has to be exceedingly strong, since the incessant heavy blows of the buckets have a tendency to cause the quality to deteriorate, the effect of which has usually been under-estimated, with the consequence that many shafts have been broken. Care should also be taken that no sand gets in between the shaft and the lining of the bearings. To prevent this happening, fixed or loose collars should be fitted close to the bearings.

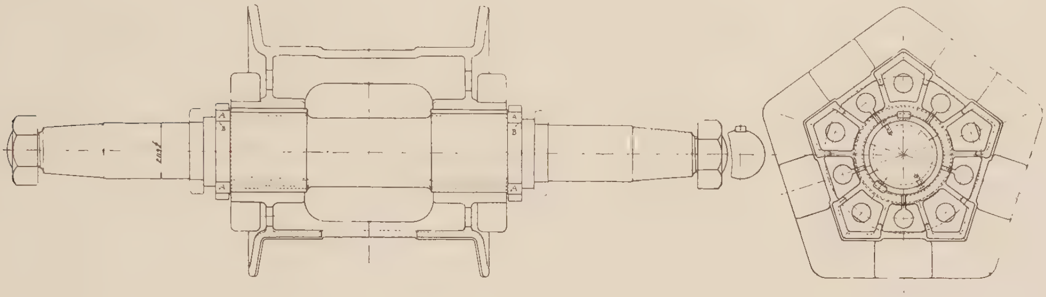


Fig. 46.

The two ends of the shaft have a conical part on which steel gear wheels are mounted in the same way as the propeller of a ship is attached to its shaft. One fact must not be forgotten, and that is that the nuts with which the gear wheels are secured should have a right-handed thread on the port side and a left-handed thread on the starboard side to prevent them from working loose.

As a rule the spur wheels and pinions are provided with double helical teeth. A better plan, however, is to replace these by machined straight teeth, and make the large gear wheel in two halves. In the first place this will lead to greater perfection of shape, and in the second place the gear wheel can be more easily detached from the shaft. Large spur wheels with double helical teeth are never truly turned, which seriously affects the smooth running of the tumbler shaft in the bearings. This method of construction may be expensive, but it will pay in the long run.

Finally, attention cannot be too strongly drawn to the fact that the pentagonal tumbler is the most important wearing part of the dredger, so that it is impossible to pay too much attention to the construction, quality and the workmanship of same.

TRANSMISSION

The transmission of motion to the top tumbler takes place through two belts on a pulley shaft; the latter carrying two steel pinions which drive the spur wheels mounted on the tumbler shaft.

In Holland, transmission by means of belts is generally preferred, this method being considered as the best owing to the belt slip that ensues in case of abnormal strain being encountered by the buckets.

The pulleys on the pulley shaft are built up of steel plates so that they shall not be unnecessarily heavy, whilst the pulleys on the engine shaft are made of cast-iron, with heavy rims, which serve as fly-wheels to secure the steady running of the engine, which, however, still leaves much to be desired, owing to the unequal resistance met with during the filling of the buckets.

All pulleys are made in two halves so that they can be more easily detached from the shafts.

In some cases the pulleys have a detachable rim so that their diameter can be reduced, and consequently the transmission of motion to the bucket chain is increased if very heavy work should require this.

With foreign dredgers the transmission usually takes place by means of gearing furnished with a friction device. As has already been said, the belt pulleys serve as such in the system observed in Holland, and they slip at the critical moments. Friction discs require much attention, as they can very easily be too strongly adjusted, a fact to which the crew does not always pay sufficient attention.

The two pinions and pulleys are keyed on the pulley shaft. It is better to do this on one side only, and to provide the pinion on the other side with a cast-on boss to which the pulley is secured. This pinion is a loose fit on the pulley shaft, and is kept in its place by two sets of rings. This method of fitting enables the pinions to be adjusted so that the teeth will mesh properly with those of the spur wheels.

Another method, which has been applied only recently, is to make the pulley shaft in two parts and join them about the middle by fixed flanges. The holes of one of the flanges are elongated to allow of a certain amount of play which renders them capable of adjustment with respect to each other. The teeth of the pinions are first made to engage those of the spur wheel, and the coupling bolts of the two flanges are then tightened.

The bearings of the pentagonal tumbler and the pulley shaft are made of cast steel and constructed in such a way that the distance between them remains constant, so that the teeth of the spur wheels and pinions always work well in mesh with each other. For this purpose the bearings are mounted on a steel foundation, upon which they are keyed.

The distance between the two shafts should be large, to prevent the pulley shaft being damaged by objects conveyed by the buckets, and also, because, should the buckets become deformed in consequence of their being drawn out, they might otherwise hit the shaft. Apart from this, however, it is never advisable to make the distance too small, since a long distance leaves one free to use a larger bucket when light material is being dredged.

The ratio of reduction of the transmission is about 20 to 1, so that at 120 revolutions of the engine the pentagonal tumbler revolves six times, which amounts to fifteen buckets per minute ; this speed may be considered about the normal. When heavy work has to be done the number is decreased to twelve, whereas with very light mud it may be increased to about twenty-five per minute.

BUCKET CHAIN

The shape and the construction of the buckets have been altered more than anything else. The changes in the shape were always aimed at making the bucket discharge its contents fully into the shoot, when passing the upper tumbler, while the construction had to be sufficiently strong in design to prevent them being stretched or drawn out when unusual resistance was met with. This is important in order to keep the inevitable repairs within reasonable bounds.

As regards the shape, a more or less truncated cone with non-parallel planes has generally been adopted; the bottom plane of the corner forming the open side of the bucket. Acute angles have been avoided as much as possible to prevent the material sticking in the buckets.

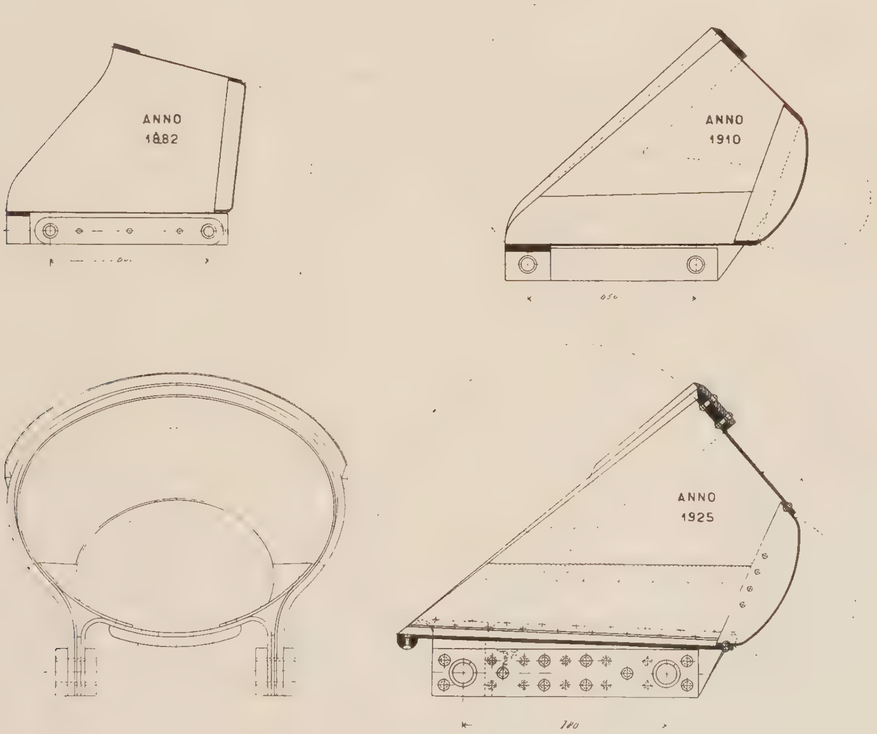


FIG. 47.

The buckets are constructed of steel plates or of solid cast steel. The latter is especially used for large buckets of about 700 litres or more, although for smaller buckets cast steel is preferred in some special cases.

Both methods of construction have their advantages and drawbacks. The plate-steel bucket is lighter, and, owing to the nature of its construction, can be more easily repaired than the cast-steel one. One drawback, however, in respect to the former is that it needs more repairing, as it has been proved in practice that the rivets always work loose sooner or later owing to the constant deformation which this bucket inevitably undergoes when digging, even though it may resume its former shape afterwards. It is also clear that the bucket is sometimes dented at the moment when it is right under the lower tumbler, owing to the pitching and tossing of the dredger. Dredging in very stiff material may also move the vessel up and down.

To prevent this type of bucket becoming indented the steel plates of which it is constructed would have to be strengthened so much that their manufacture would involve extra labour and consequently they would become more expensive ; while their weight would come very near to that of the cast-steel bucket. Thus the latter is being adopted more and more for very large dredgers.

An attempt to illustrate the above is made in Fig. 47, where, side by side, plate-steel buckets of 250, 400 and 650 litres capacity with a weight of, respectively, 300, 600 and 1,250 kg. are shown.

The parts that are exposed to the greatest wear and tear are, besides the pins and bushes, the lip and the bearing surface on the underside of the bucket which comes in contact with and passes over the tumblers.

The pins are usually made of forged " Era " manganese steel. They were introduced in Holland in 1891 by Hadfields, of Sheffield, and have never yet been surpassed. For reasons of durability the pin should be of large diameter. and if this is adopted the bushes will also profit. They are made either with a round or a square head. In the first case the pin can turn round freely, while in the second case this is rendered impossible by a fixed cam or projection on the outermost intermediate link, fitted close against the head. Both systems are used, but, although the latter apparently is preferable, the round head is more largely used with plate-steel buckets because experience has shown that it is very difficult to keep the head of the bolt close against the cam all the time. Consequently the projection is gradually worn away by the head, until the pin becomes free to turn round in the links. Apart from the fact that the link with cam is more expensive than the ordinary flat link, the latter can be more easily repaired when this is necessary. This is an advantage as the repairs are usually done in the workshop of the dredger.

The drawback with the rounded headed pin is that the pin wears both link and bucket bushes, and as the diameter of the pin is reduced by both it will break sooner, for it may be safely assumed that the pin always bends a little in the direction of the force which is being applied to it. In a revolving pin this bending action occurs first in one direction, then in another ; consequently this increases the chances of the pin breaking sooner or later. Hence this is another reason for using pins of large diameter.

The bucket bushes are of cast " Era " manganese steel, these being less expensive and somewhat harder than the forged ones. They are provided with a slit, and are driven with great force into the buckets. Of late the bushes have been provided with a slit, 10 mm. wide, into which a steel cotter is driven. This practice should be generally adopted as it facilitates the renewing of the bushes. By driving the cotter out again the old bush can be quickly removed, which otherwise would cost much time, as the bush gets stuck to such an extent that it can only be driven out with the utmost difficulty. The bucket lip wears, especially in the middle, and is therefore furnished with a renewable lip of " Era " manganese steel which at the same time serves to strengthen the bucket.

It is obvious that the bearing surface of the bucket should be as broad as possible, for not only does this make the bucket bush longer in length, but it also largely mitigates the excessive and inevitable wear caused by the tumblers.

The only means known at present to protect the buckets as much as possible from being worn by the tumblers is that shown in Fig. 48. The bucket links are made of cast " Era " mangagese steel, with cast-on bases both on the outside and inside ; the former serves to make the bearing surface as broad as possible, the latter to guard the bucket against wear. It has been found that these links work loose if they are not very firmly secured to the bucket, owing to the latter knocking against the pentagonal tumbler, the rivets receiving the greater part of the blow.

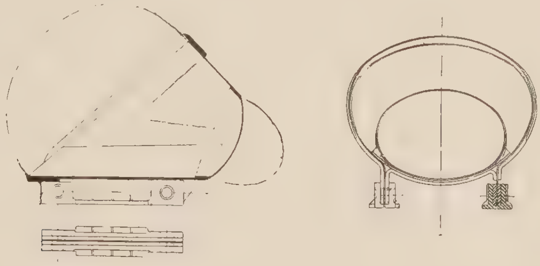


Fig. 48.

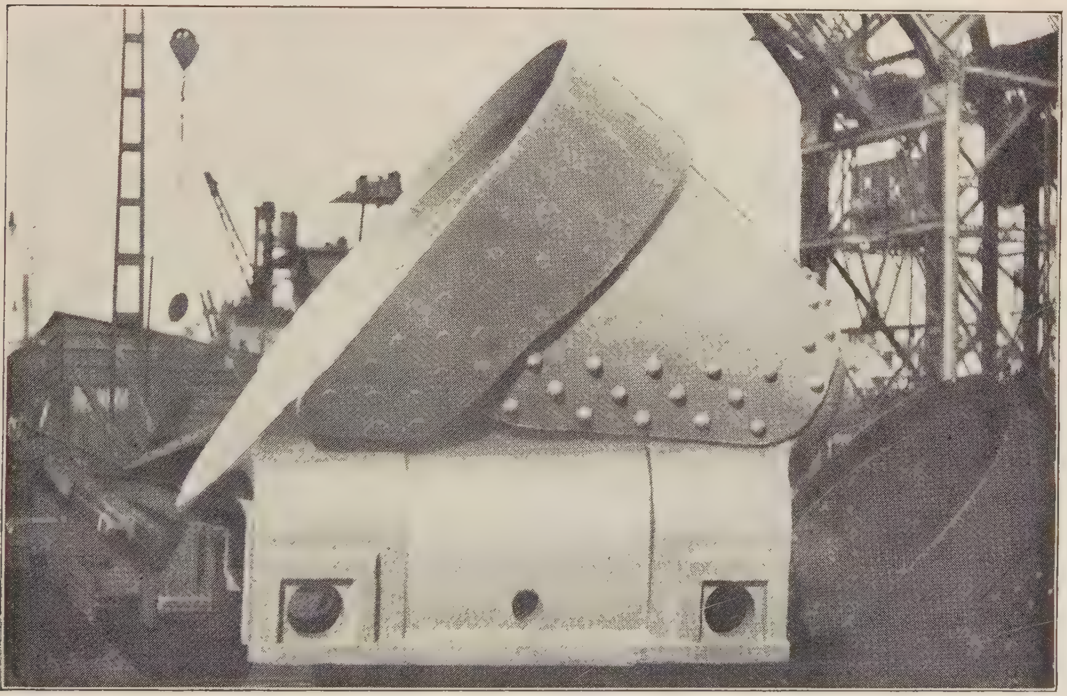


Fig. 49.

The buckets are connected by four intermediate links of sufficient width, in which "Era" manganese steel wearing bushes are shrunk or forced.

The cast-steel bucket (Fig. 49) consists of a cast-steel bottompiece, to which the shell plate with the cutting edge or lip is riveted.

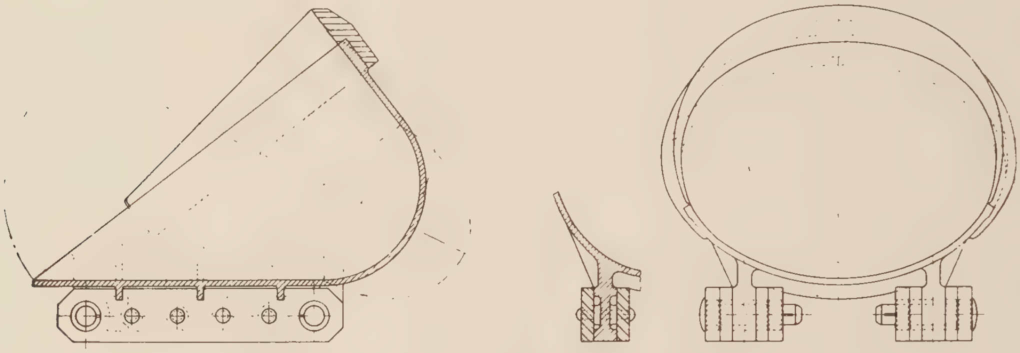


Fig. 50.

In many cases the shell plate is done away with and the whole bucket, to which a cutting edge is riveted, is made of cast steel. The cutting edge is made rather thick in the middle, tapering from the middle to the back, the whole being made of manganese steel.

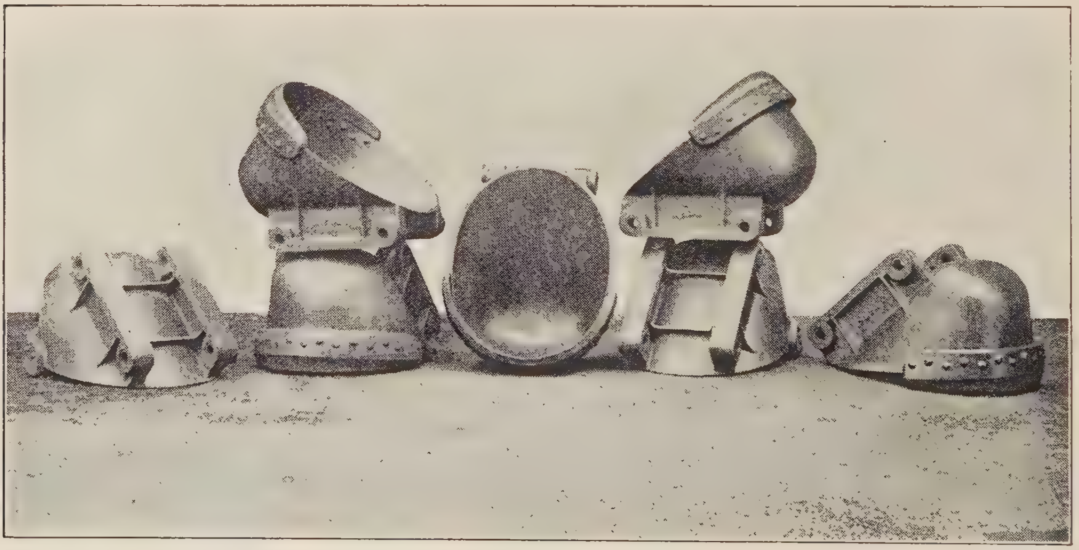


Fig. 51.

With a bucket entirely of cast steel it is advisable to fix the cutting edge to the inside, as it will then serve as a wearing plate as well where the buckets wear most, while it has the additional advantage that the edge cannot be so easily torn off from the bucket.

It may be mentioned here that the cutting edge forms an important part of the construction of the bucket built up of steel plates, which is not the case with cast-steel ones.

With the latter kind a single intermediate link is generally used on either side and the square head of the pin is countersunk into the casting.

Many builders, however, prefer these buckets with riveted-on or cast-on bucket links and two intermediate links on either side (Fig. 50) ; in the first place, the bearing surface can be renewed by turning the links or replacing by new ones, which at the same time partially renews the bucket bush-holes ; in the second place it is safer to have four instead of two intermediate links, for, in spite of their thickness, they often break. Fig. 51 shows the same construction without loose bucket links.

To each bucket chain there is a set of fork links, which are in readiness in case it should be necessary to place two sets of intermediate links between each pair of buckets.

On board of every dredger there are also two drawbars, which serve to connect the ends of the chain when mounting it, and which are also indispensable when the bucket chain has to be repaired. Fig. 52 shows a draw bar used with plate-steel buckets, while Fig. 53 shows one used with large cast-steel buckets in which holes have been cast on the underside to take the two end links of the drawbar.

LADDER WINCH

When the enormous weight of the complete bucket ladder and bucket chain is taken into consideration it is clear that the hoisting gear is also an important item. The construction of the framework, upon which the hoisting gear is placed, is of heavy proportions, and the two side members, which are firmly connected together, are strongly secured to the vessel on each side of the well.

Against one of the sides a cast-iron bed plate is mounted, on which a steam engine of two cylinders with link motion and other accessories are placed. These cylinders operate a crankshaft fitted with a steel worm, which in turn works a worm wheel surmounted with a bronze toothed rim. Both are encased in a cast-iron oil box. The worm wheel shaft then transmits the power by means of steel reduction gearing to two large spur wheels mounted on the shaft that carries the hoisting drum.

In the middle of the drum there is a cast-iron stud, round which the centre of the lifting wire rope is attached. Both halves of the rope are wound round the drum and the ends are connected with the bucket ladder. To prevent the wire rope being damaged by the buckets passing it a heavy wrought-iron bar or some chain links are placed between the ladder and the rope.

Thus the ladder is suspended from two single wire ropes ; and an additional wire rope for the purpose of safety can be attached to the ladder at other points of suspension, so that, should the ladder ropes break, the ladder can be lifted again in the minimum of time without any trouble, by simply removing the broken cable and attaching the safety rope. It is chiefly for this reason that contractors prefer this method of construction, and they have introduced it into the largest dredgers, in spite of the fact that the rope has, in some instances, a circumference of 25 centimetres.

Another advantage is that these single cables wear longer than when two or more ropes working in lifting tackle are used.

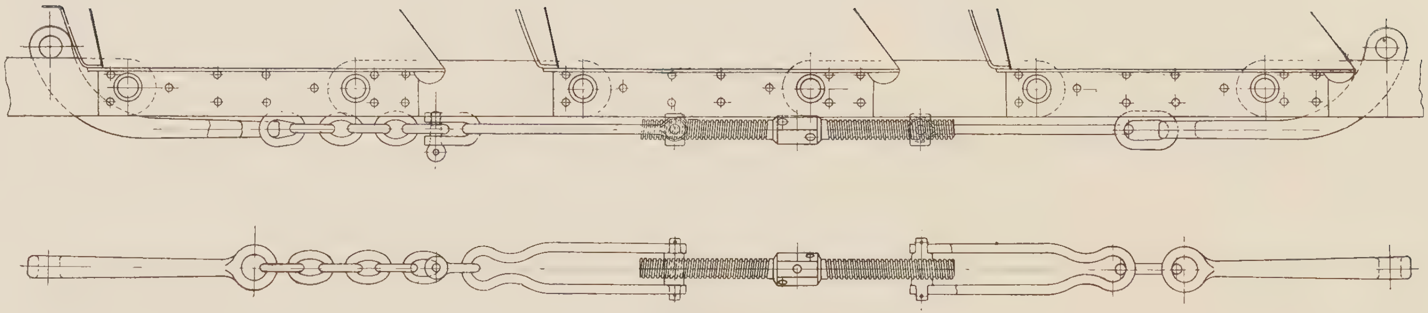


Fig. 52.

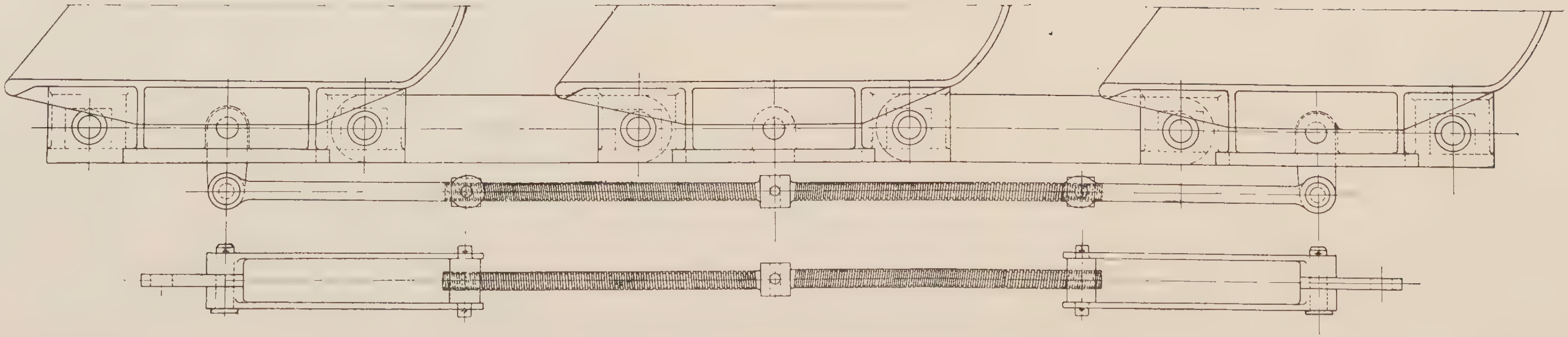


Fig. 53.

For, since the single ropes always remain stretched when not wound round the drum, there is less danger of the wire rope losing its galvanized coating than when used in conjunction with the usual lifting tackle. Owing to the abrading action on the cable as it passes round the pulley sheaves, especially on the lower pulley, which often works in sandy or salt water, the rope rapidly loses its zinc covering, which allows the rope to rust and consequently quickly wear away.

The breaking of the ladder ropes occurs but seldom, and, as has already been mentioned, for that reason it is better that the safety ropes be kept in the storeroom when the dredger has no heavy work to do and is working in places where the ladder need not be raised quickly.

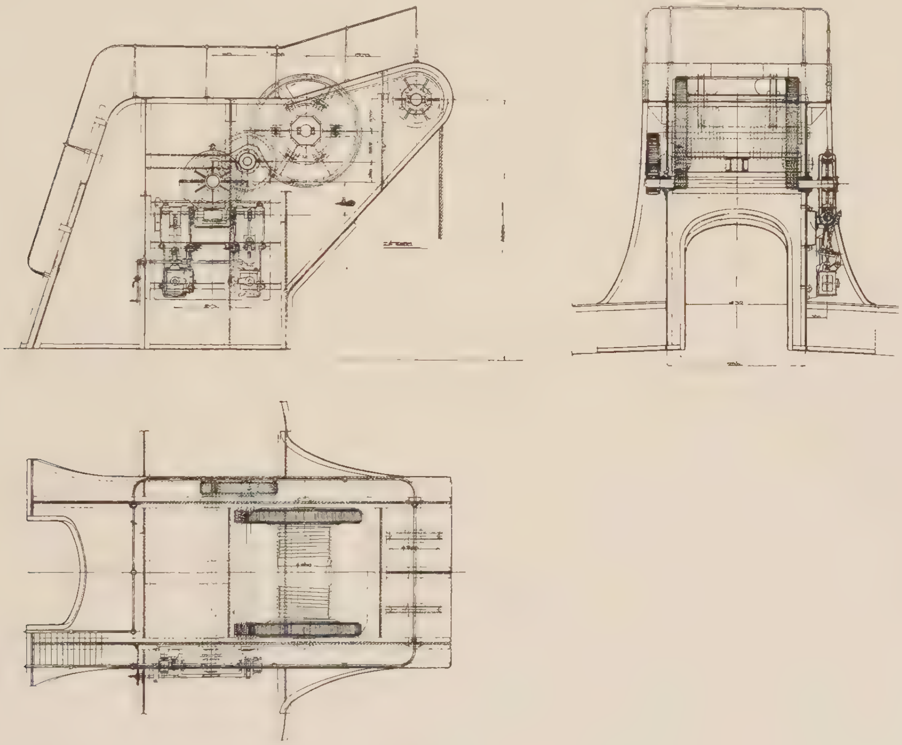


Fig. 54.

With the latest dredgers guide-pulleys, or rollers, fitted on a shaft, are mounted in front of the hoisting drum, over which the steel cables may be led, and brought sufficiently forward to enable the ladder, when in a lower position, to be lifted without any difficulty (Fig. 54).

A slewing crane for hoisting the heavy anchors on board, and for placing the buckets on the ladder when mounting or repairing the bucket chain, is placed on top of the ladder crane; it can also be used to lift the bottom tumbler from the ladder when this has to be renewed. When the dredger works in ground, in which tree trunks or stones are found, this crane may also be used for removing them if no other hoisting gear should be available for this purpose.

The ladders of dredgers with very large buckets, of 1,000 litres or more, are raised by means of a pulley block, in which case the engine with a complete winch is placed in the forepart of the ship above the floor riders. As a rule the ladder can then be lowered by means of a brake and the dredger master has all the handles required for operating it within his reach.

It is strongly advisable to convey the fresh steam from the boiler through this winch towards the front-end winch; as the latter is nearly always working, the accumulation of condensed steam in the piping is prevented in this way, which accumulation would certainly take place if the ladder winch were placed at the end of this piping.

FRONT-END WINCHES

These steam winches have two cylinders bolted to the frames, and are placed on a separate bedplate. They are equipped with the usual link motion to enable the engine to be worked in a forward or reverse direction.

The transmission to the chain head or rollers takes place through steel wheels with straight teeth or double helical teeth. Often a fixed smooth head of chilled iron pinned to a heavy shaft is preferred. The other end is provided with a smaller head, which is used for bowsing the barges alongside, and various other proceedings.

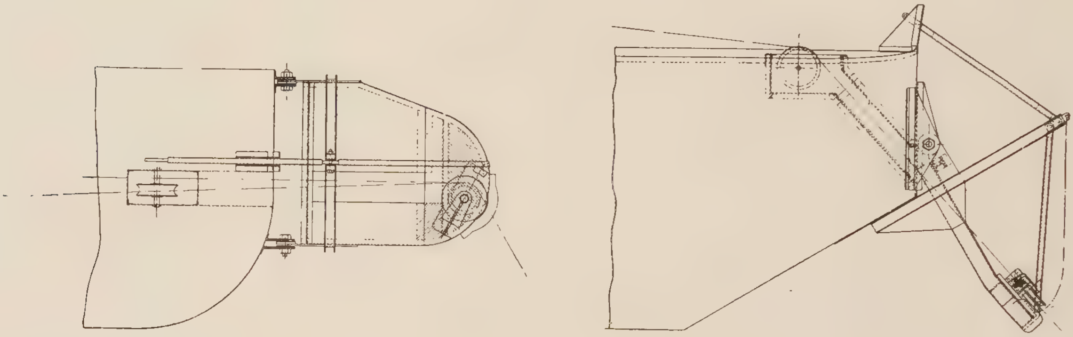


Fig. 55.

With large dredgers also a chain or steel wire rope roller is used, which is placed between the frames, and carries a friction disc and clutch. In other cases, again, a method is preferred whereby either chain or steel-wire rope may be used at will.

The deck beams are strengthened by means of web plates in those places where the winches are mounted. Below, the chain boxes are placed on balls or travelling rollers to prevent kinking of the chains.

The side chain is guided towards the stem-hawse hole roller; because of the difficulty to load the back part of the hold of large barges sufficiently this hawse hole should be placed as far forward as possible. For this purpose some dredgers are equipped with an easily detachable projecting platform which carries a hawse at its end.

For the same reason the chains are, in some cases, guided through pipes towards a roller attached to the bottom of the vessel.

This method has not proved very practicable when the chain got fouled or broken, and it has led to a combined construction of the latter method with the platform.

A hinged platform is attached to the vessel so that the hawse hole came below the level of the water: if required it can be lifted out of the water again without much trouble (Fig. 55).

In case the dredger has to work alongside a quay wall or in high-level ground, a second hawse hole is placed above the bulwark, which, like a leading block, can follow all the movements required to guide the chain in the right direction.

STERN WINCH

The construction of the stern winch is similar to that of the front-end winches, but with this difference, that this winch is furnished with a chilled iron-head on either side and a chain roller with friction and grip pawl between the frames. In the case of very large dredgers the winch heads are replaced by rollers with a friction pulley and brake.

The chains are all guided by ordinary hawse holes towards fixed chain boxes.

BOW WINCH

As a rule steel-wire rope is used for the bow cable and a winch fitted with a drum which can contain about 300 metres of wire rope. The reason for using a wire rope instead of a chain is that a heavy bow chain can follow the motion of the vessel less easily than a wire rope. To facilitate these movements still more the cable is supported halfway by a pontoon, when the dredger is working in open water. When dredging in shallow water the cable is guided by a gas pipe fitted in the centre of an oil barrel.

This winch, too, has two cylinders with the usual forward and reverse link motion, the transmission to the drum taking place by means of steel gearing.

The drum is fitted with friction pulleys, brake, and a heavy pawl; the pinion on the large spur wheel can, moreover, be put out of gear. Instead of one pawl, two pawls are usually preferred, while the friction pulleys of all the winches are of the largest possible diameter, so that less force is required when the friction pulleys are put in or out of gear.

Although this winch is usually placed alongside the main framing, some people prefer placing it midships under the shoot in a separate deck cabin, whereby the engine is efficiently guarded against splashing; moreover, more room is left alongside the main framing, as in this case only the drum, with its appurtenances, protrudes from the latter.

The bow-wire rope can be guided at will over the deck or to a raised hawse hole against the ladder-winch framing. The hawse holes should be provided with vertical or horizontal guide rollers to prevent the wire rope wearing out the hawse holes. The steam supply can be regulated not only at the winch, but also from the dredger master's place.

SHOOT WINCHES

The engine cabin has been extended so far in the direction of the main framing that sufficient room has been gained for placing the shoot winches. These work with two cylinders, and have link motion. Here, too, the transmission takes place through steel-gear wheels to two wire-rope drums with grip pawl, one for each shoot. Sometimes one winch for both drums is deemed sufficient, in which case the drums are equipped with a friction pulley. To avoid the latter many people rightly prefer two separate winches.

MISCELLANEOUS

Besides the steam winches mentioned, a steam or hand winch with wire-rope drum, called a " flood winch," is found aft. It serves to lower in certain cases, a reserve stern anchor, and is equipped with two winch heads to move the barges alongside the dredger.

When working in the mouths of large rivers this arrangement enables the work to be continued as long as possible when the tide is coming in.

Though the position of the " flood winch," as it has been described above, is the most common, yet with large dredgers another arrangement may be preferred. Thus, for example, a winch which only works the back chain and the flood wire may be placed midships, while on either side a winch may be placed for working the two hind chains. In this case the two side winches are provided with heads for bowsing the barges.

The idea of uniting all the winches into one central winch, as is already the case with ore dredgers, and as is sometimes done abroad, has often been considered ; but, although it decreases the first cost, it increases the risk of breakdowns of the transmission to the various drums, while the crew cannot be reduced, as they are wanted for other work, such as repairing the bucket chain and dropping and weighing the anchor.

The exhaust steam of all winches and auxiliary engines may be led at will to an auxiliary condenser or allowed to pass freely into the air.

Just as the engineer has all the handles for controlling his engine within his reach, so also has the dredger master in his place near the ladder winch :—

(*a*) A telegraph and speaking tube to the engine room ;
(*b*) A handle for regulating the water supply in the shoot.
(*c*) A handle for working the bow winch.
(*d*) A bell for signalling to the deck crew.
(*e*) (Sometimes) a handle for stopping the main engine.

In the engine room there are, besides a complete inventory, a work bench, a boring machine and a smithy.

Besides the pontoon already mentioned, there is attached to each dredger an anchor boat, this being a wooden row-boat for four oars, in which a hand winch is placed, with a corresponding hawse roller on the stern, which is used for weighing the anchors.

Finally, besides a complete inventory, each dredger requires certain spare parts, and it is advisable to have them always at hand, to prevent unnecessarily prolonged periods of inactivity when repairs and renewals become necessary.

Of these the principal are :—

A top tumbler complete with shaft and gear wheels.
A bottom tumbler with shaft and blocks.
A receiver door for the shoots.
A few buckets, bolts, bushes, links, guide rollers, roller-bearings, winch heads, hawse rollers, and a set of pinions for the pulley shaft.

For use in foreign waters several dredgers with a bucket capacity of 1,200 litres have been built in Holland (Fig. 56). The same dredger on the English system is shown in Figs. 56A, 56C, 56D, built by Messrs. Lobnitz & Co., Ltd., of Renfrew (Scotland).

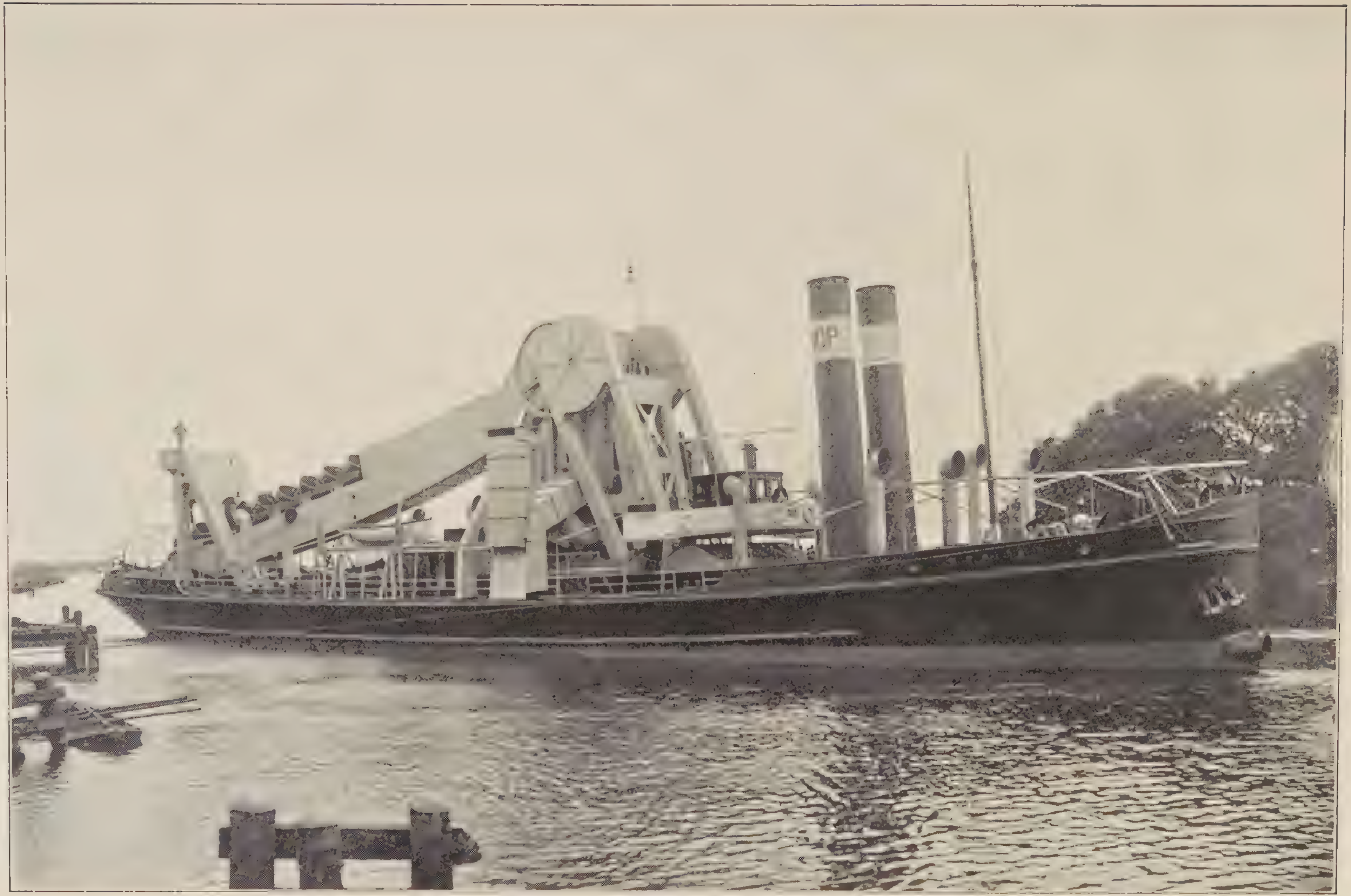


Fig. 56.

They are all of the ordinary ship's model and self-propelling. Private concerns and contractors will certainly not remain behind for long in the adoption of the larger dredger, but although this will depend to a great extent on competition, it will be chiefly determined by the class of work that will have to be executed in the future.

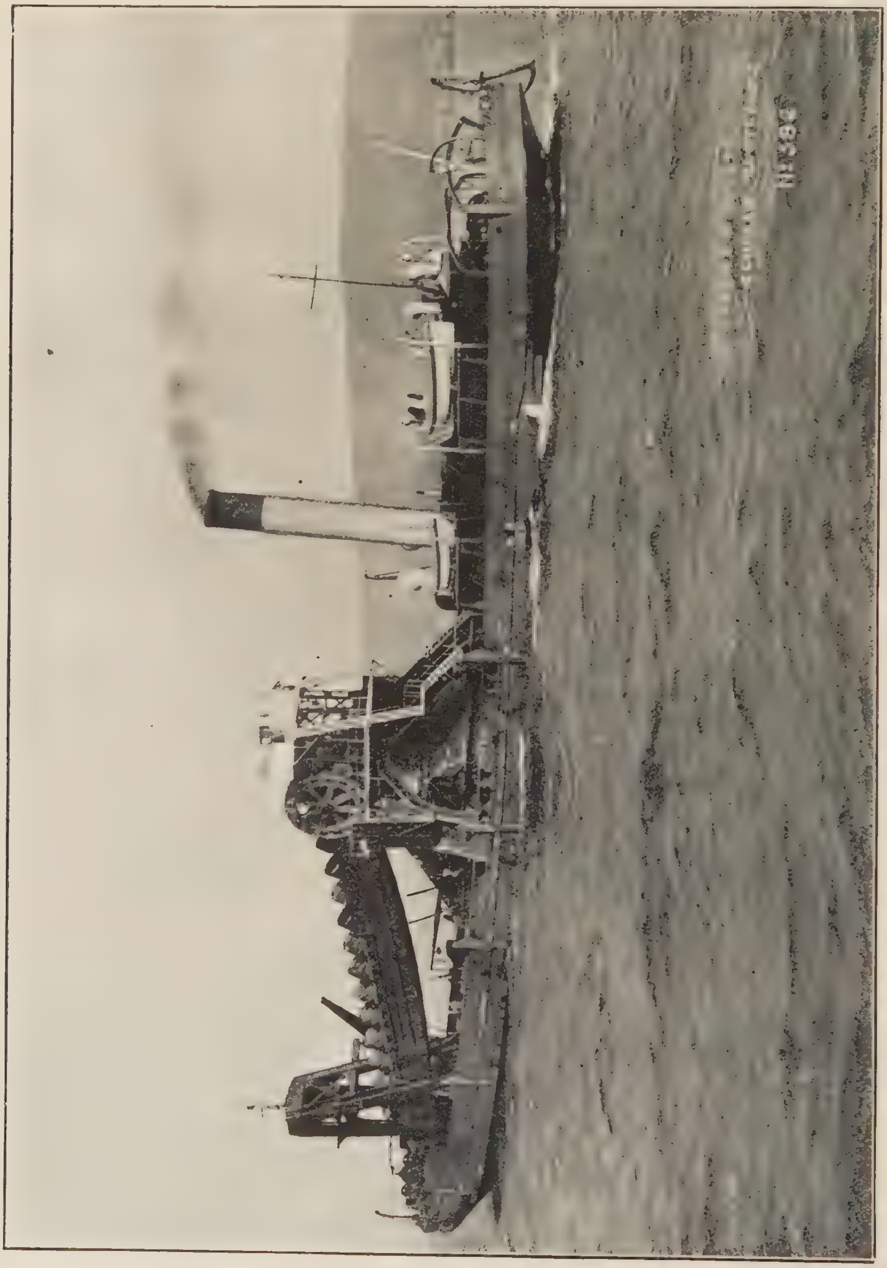


Fig. 56a.

Sometimes these dredgers possess their own hold of 800 to 1,000 cubic metres capacity, into which the spoil can be discharged. Like the hopper barges, the holds are provided with doors to enable them to discharge their contents quickly. The doors are closed by means of a steam winch or by hydraulic power.

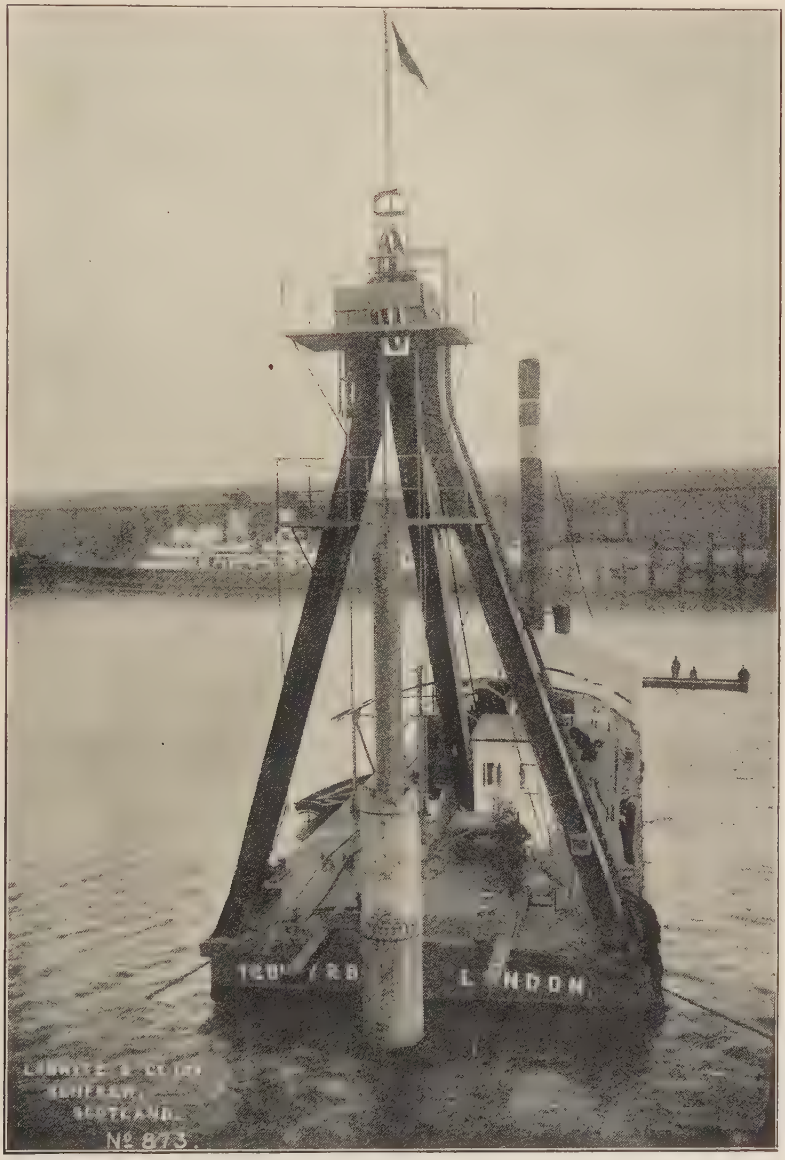


Fig. 56b.

This kind of dredger is only used under very special circumstances, usually in the mouths of rivers. As much time is lost in the continual unloading and the taking up of all the mooring chains they are not to be recommended from an economical point of view.

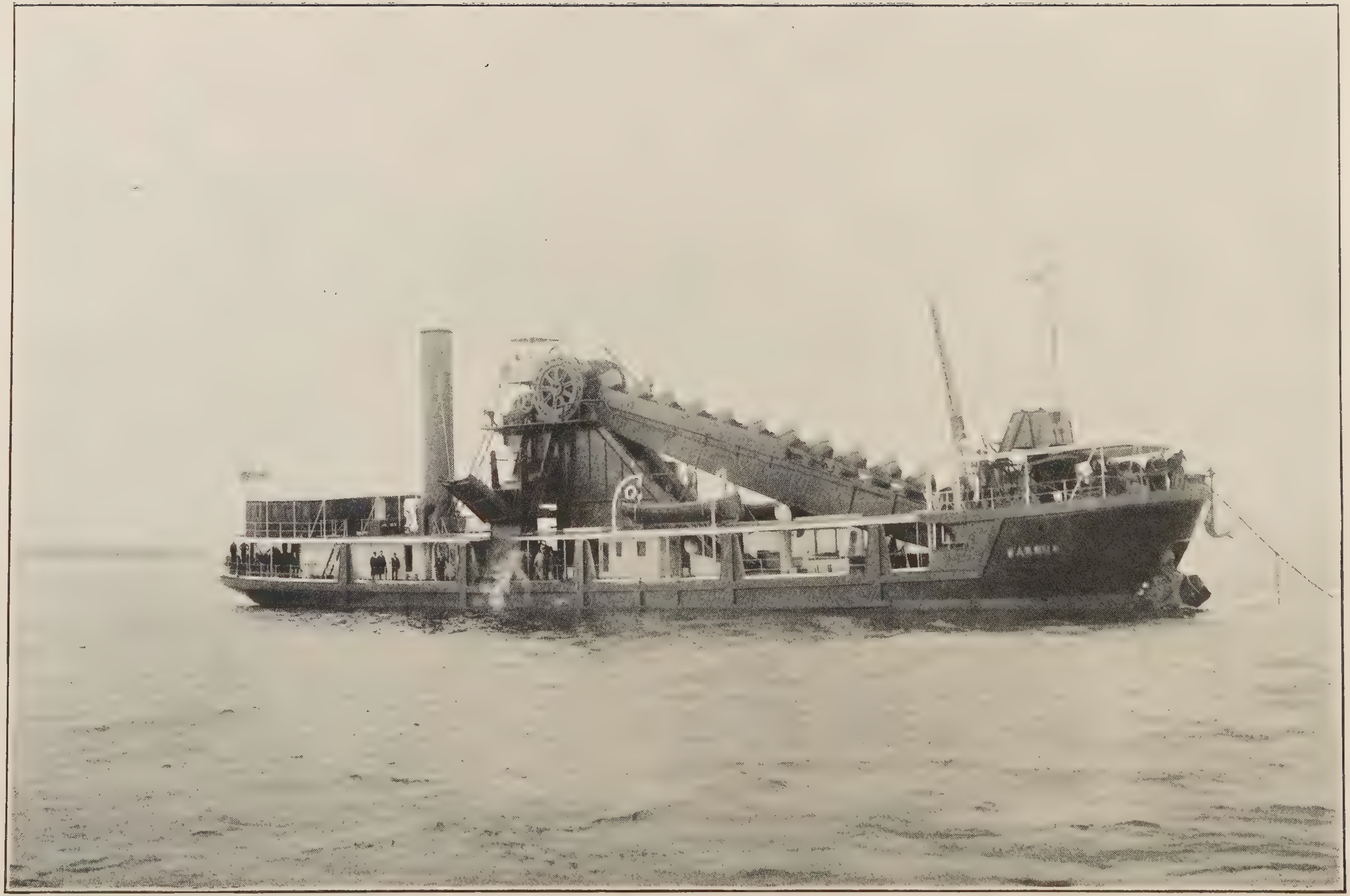


Fig. 56c.

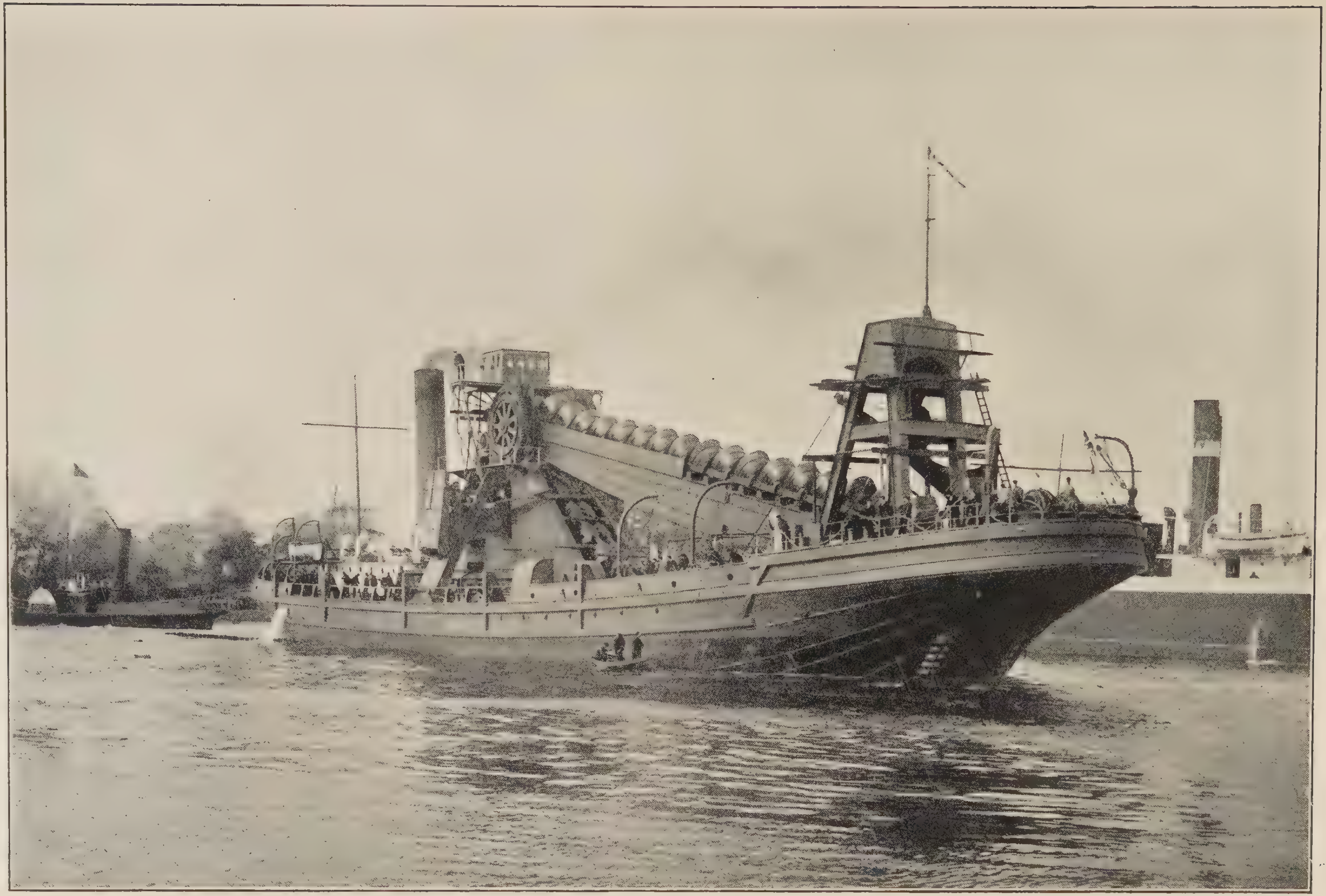


Fig. 56d.

It may be added that the steering gear and the accommodation for the crew in these large dredgers are equal to those of a sea-going ship.

Sometimes dredgers have to deal with rocky ground which they cannot remove until the rock has been split by a rock breaker (Fig. 56*b*) ; this being a heavy iron pile, steel pointed. The rocky ground is rammed by this pile on those places where the bottom has to be deepened.

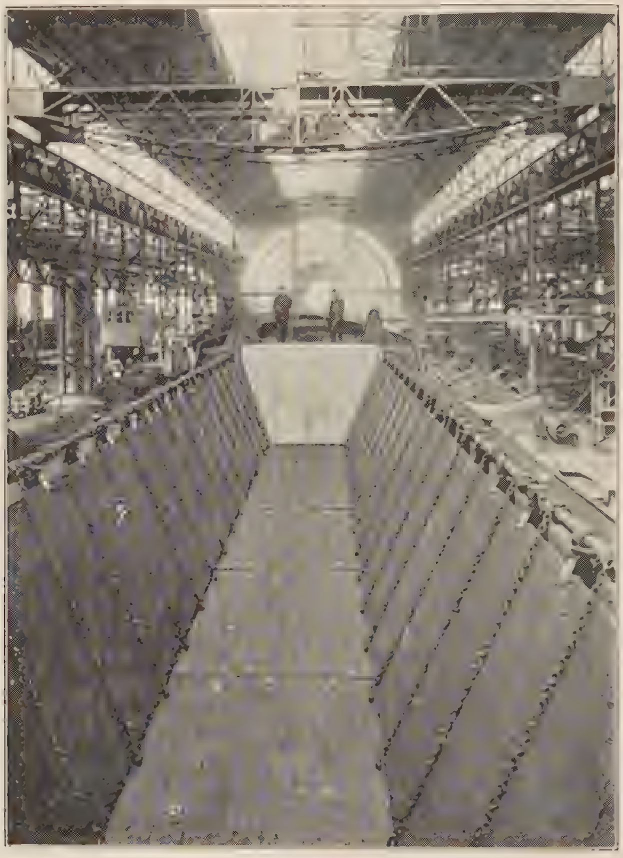


Fig. 57.

BARGES

To return to the barges in which the dredgers discharge the dredged material, the capacity of these, too, has been proportionately increased. It now varies from 200 to more than 500 cubic metres. In most cases the barges are closed, and they are still called elevator barges, sometimes being built in the shape of ordinary sailing vessels. They are emptied by means of a suction dredger (Appendix B).

Of late years barges are often employed which can be used either as hopper barges or as closed barges. In this type the chains of the doors are connected to the sides of the vessel, while a worm wheel, or winch, has been substituted for the ratchet wheel.

Some of the many varieties of this kind are shown in Figs. 57, 58, 59 and 60. Fig. 60 shows a hold with vertical sides specially constructed for stiff material.

If the spoil has to be discharged into the sea, sea-going "steam hoppers" are used for preference. These are hopper barges built like ordinary sea-going ships with steam power (Figs. 61, 61A, 61B). The doors are closed by steam power, and opened by removing a cotter on each chain, the hoisting apparatus being first put out of gear.

The capacities of these vessels vary from 300 to 600 cubic metres, though some of even still greater capacity have been built, while various improvements in their construction have been made, the same as with the barges.

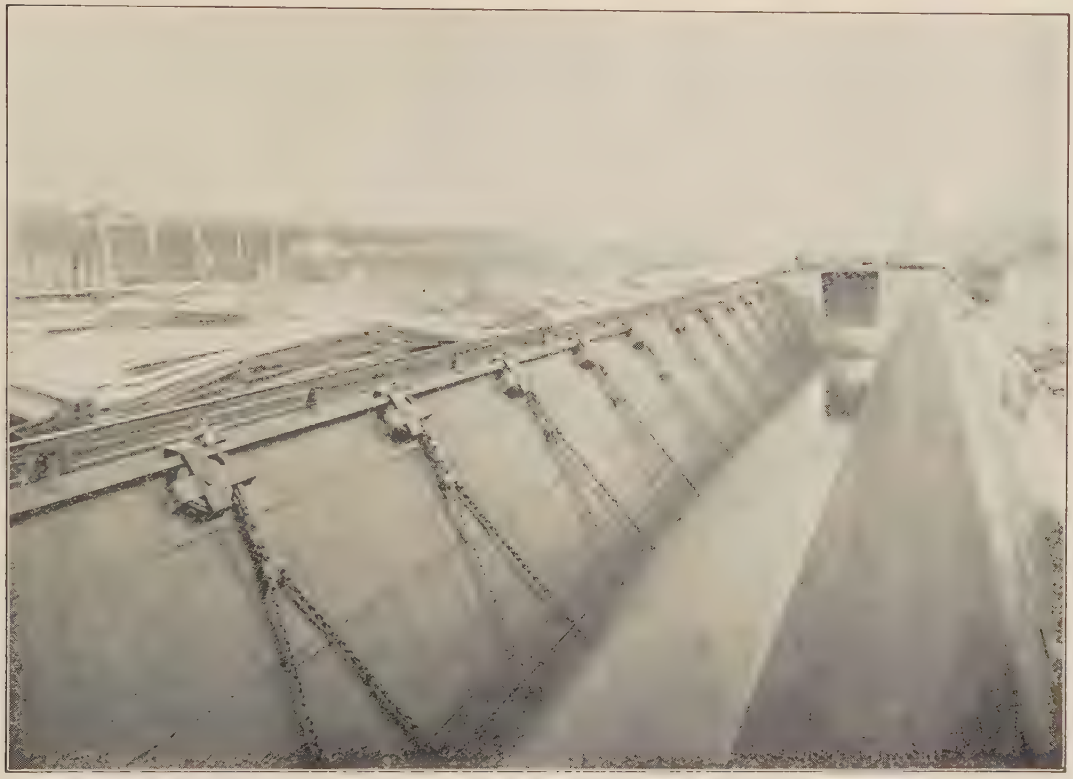


Fig. 58.

TUGS

In giving a description of dredger appliances, the tugs must not be neglected, as they undoubtedly play an important part in the dredging industry. Although they are very similar in build to other tugs, yet they have to be designed to meet with the special duties they have to perform when used in connection with dredging operations (Fig. 62).

In constructing them it has to be borne in mind that they must be able to turn easily and quickly, be very powerful, and their draught should be as shallow as possible.

The tow rail or tow hook is placed midships, behind the funnel, to render the towing of the barges easy of operation.

To meet the above requirements the proportion of length to breadth is seldom more than five to one, and it is advisable to equip the tug with a sluice keel at the stern as well as at the prow.

Both at the fore and aft there is a water tank, and water can be pumped from one tank to the other to balance the vessel.

The funnel is arranged so that it can be lowered when necessary.

The ship which is seaworthy has stern bulwarks that slope inwardly, and the prow rises vertically from the water, so that a heavy semi-circular fender forms the outer line of the tug. It is advisable to place a salvage pump on board and to equip the vessel with a steam anchor and steering winch when the vessel reaches dimensions which call for these.

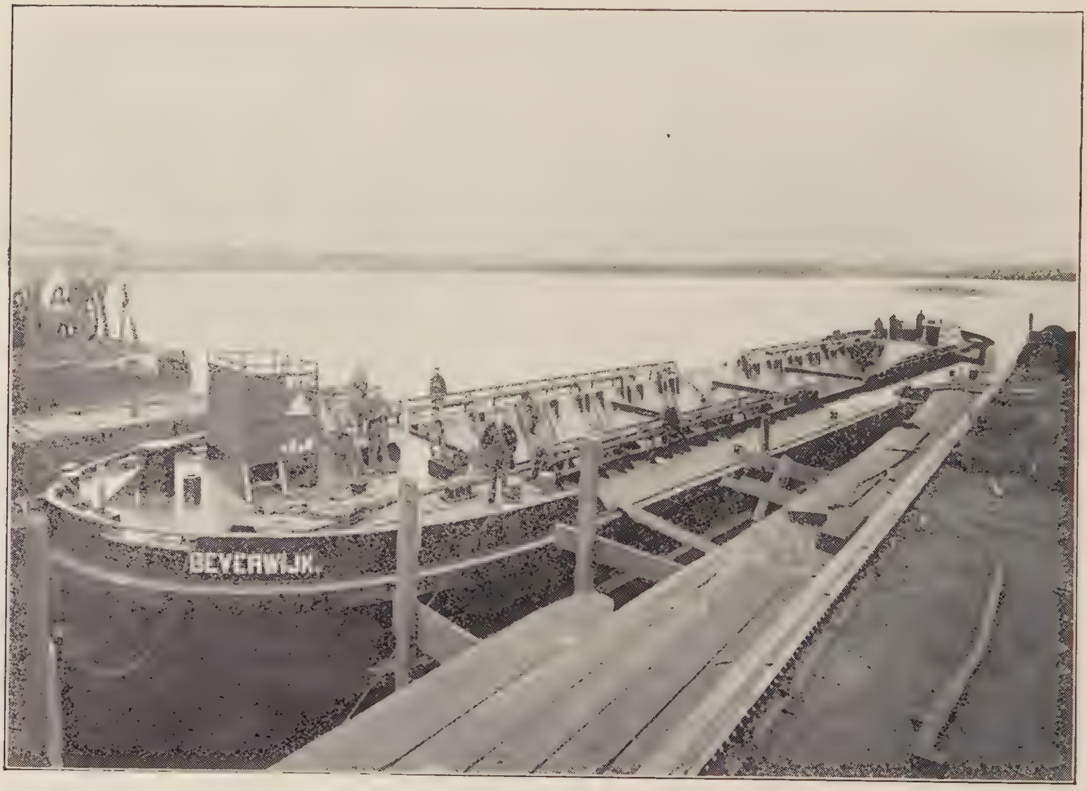


Fig. 59.

GRAVEL DREDGER

Before concluding we must give a short description of dredgers used for other purposes. In the first place, there is the gravel dredger. In these dredgers a grating is placed at a short distance above the bottom of the shoot. The dredged gravel and sand are discharged on to this grating (Fig. 63), and a large quantity of water is pumped upon it by a centrifugal pump. The water washes the sand into the river again, and the gravel is conveyed to gravel barges lying alongside the dredger. Sometimes the sand is conveyed to a barge moored on one side of the vessel while the gravel is conveyed to another on the other side.

GOLD DREDGER

Another important application of the dredger is that of winning gold and tin. The gold dredger has already been in use for more than twenty years, at first in Australia, and was afterwards introduced, greatly improved, in North America. It has since been very usefully employed in other countries, such as California, British Columbia, Siberia, etc.

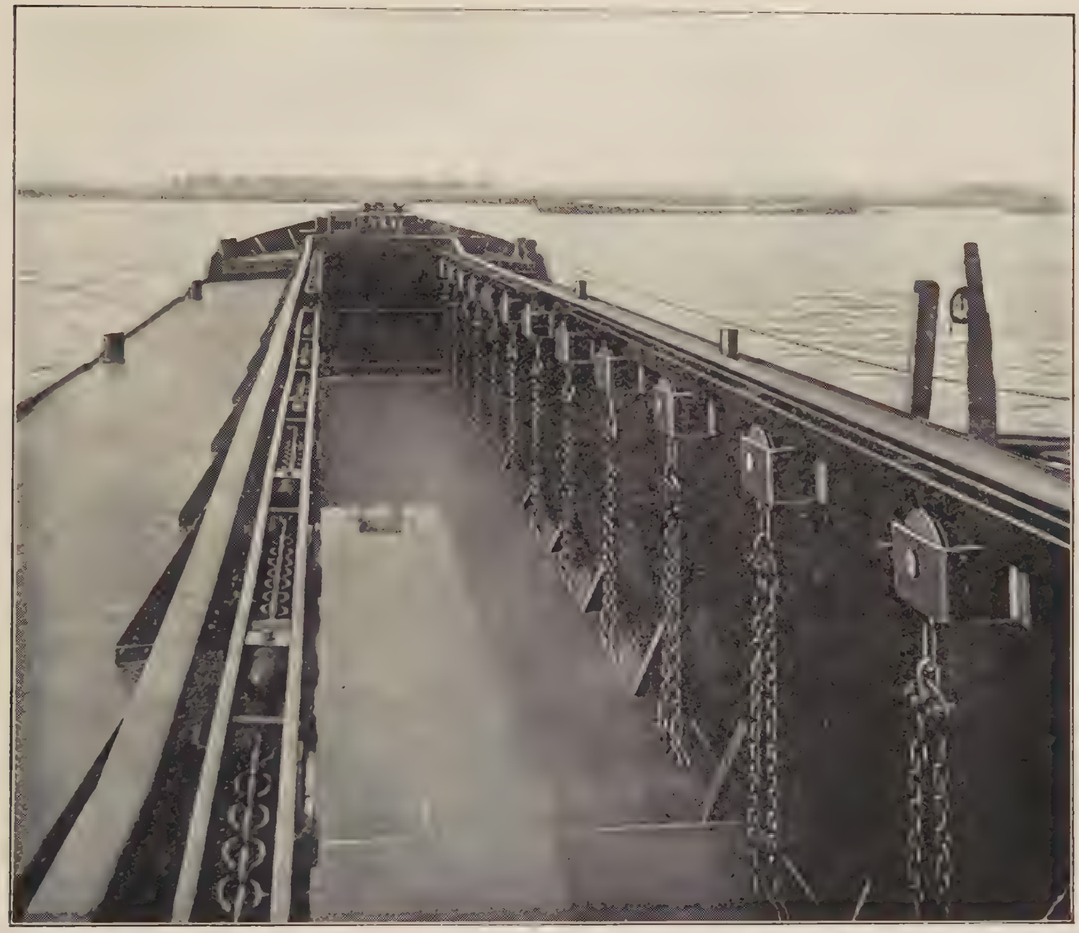


Fig. 60.

These dredgers cannot only operate in rivers, lakes or sea, but also in ground where a basin can be dug and then filled with water. In the latter case the dredger is erected

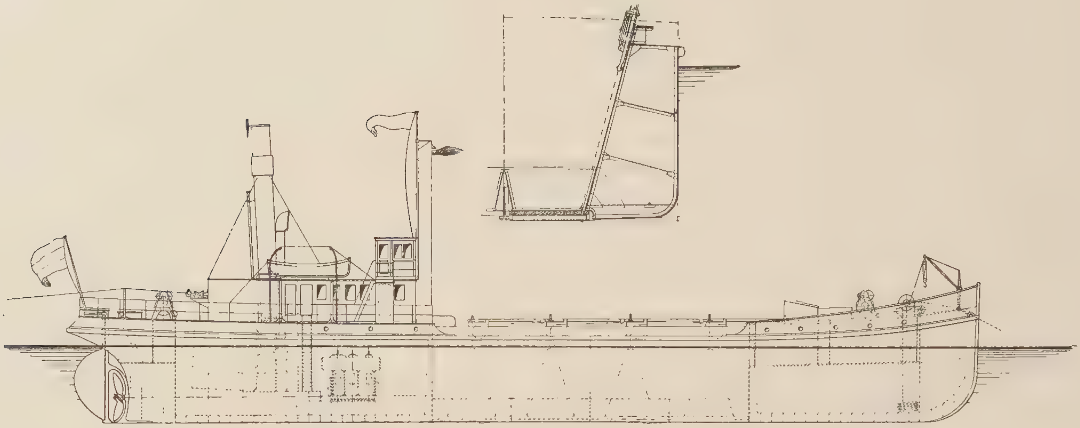


FIG. 61.

on the spot before the water is let into the basin, and the water is afterwards kept up to the required level either naturally or artificially (Fig. 64).

Gold dredgers are flat, broad vessels with an open well. Inside the vessel there is only a tank for ballast, fresh water or residue, while the complete plant, both for

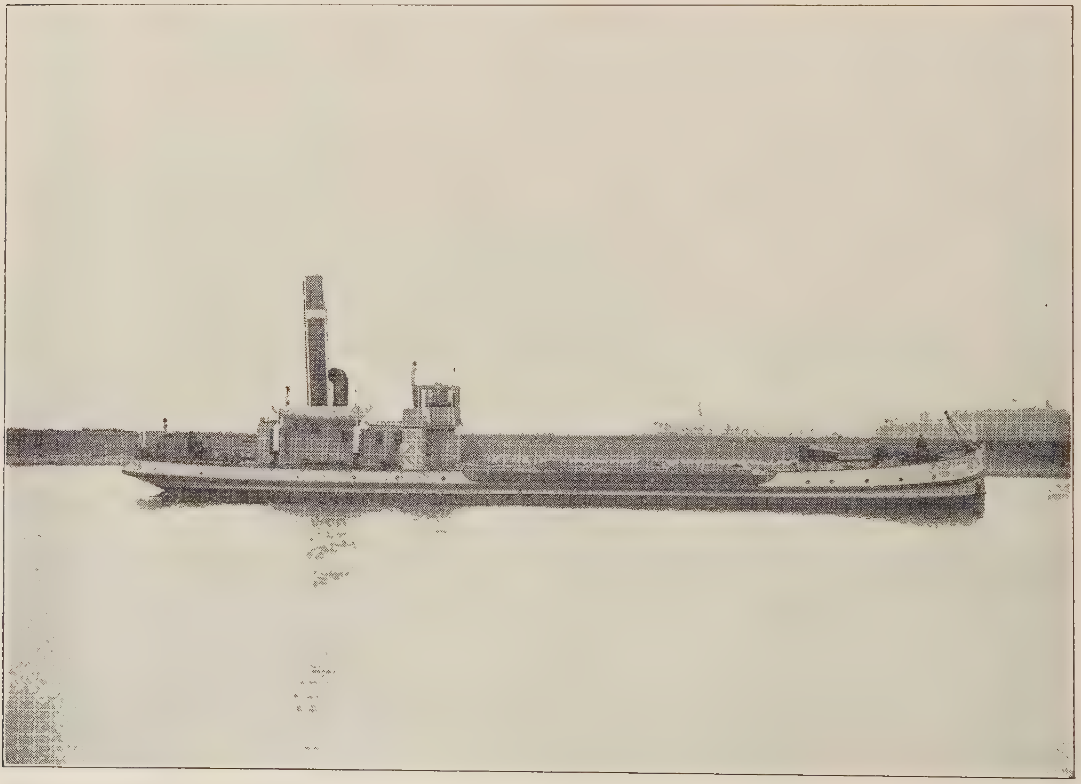


FIG. 61A.

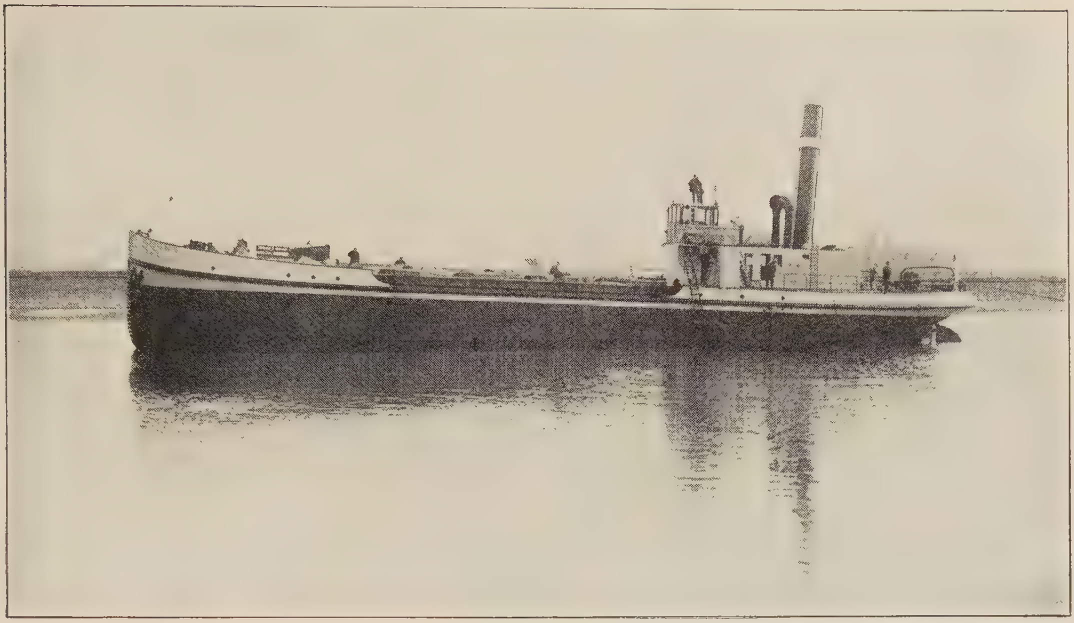


FIG. 61B.

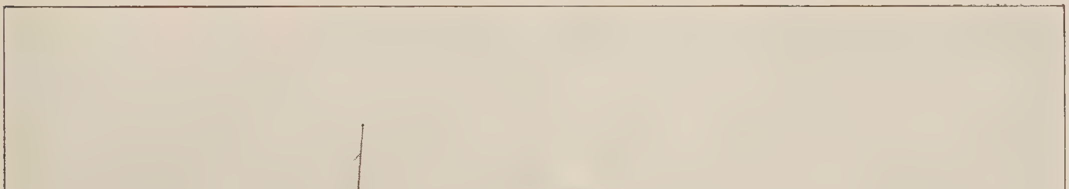


FIG. 62.

dredging and for washing the gold, is mounted on the deck. As a rule there is no accommodation for the crew.

The bucket chain is driven in the ordinary way by a vertical or horizontal compound engine, and the contents of the buckets, which vary in capacity from 140 to upwards of 300 litres, are discharged into a shoot, which conveys the spoil to the washing plant.

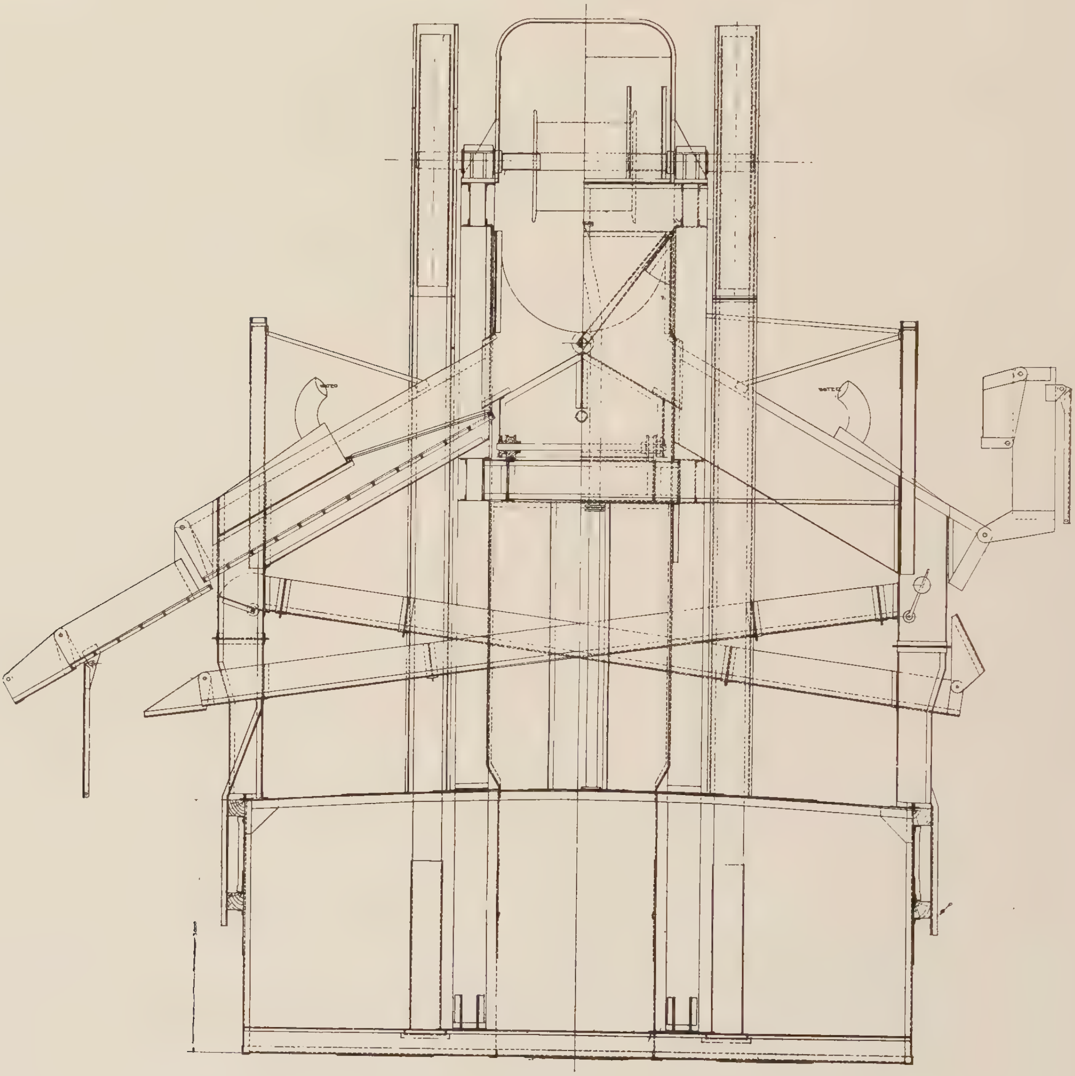


Fig. 63.

The washing plant consists of a rotary screen ("Cribleur"), *i.e.*, a cylinder built up of plates perforated with conical holes. The size of these holes at the small end is 10 mm., and the larger diameter is always placed on the outside surface of the drum to prevent the holes being choked. These cylinders are covered on the inside by lining or wearing plates, which, however, do not cover the holes, in which correspondingly larger holes have been punched. The wearing plate may also be placed at some distance from the cylinder plate.

This rotary screen is placed behind the main framing, with its shaft in line with the centre of the vessel, at an inclination of 1 in 10. Each end of the screen rests on a set of travelling rollers, over which it revolves. The spoil is conveyed into this drum at the top, while, on the other side, one or more pipes discharge a powerful water jet over the entire length of the " screen." This combined action pulverises the earth, assorting it as it were, so that all fine particles, including the gold ore, are washed through the holes of the " screen." The larger pieces of soil, stones, and wood are conveyed towards the lower end of the drum where they fall into what is called a " stone shoot," by which they are conveyed to a distance of some metres behind the vessel, and dropped on to the buckets of an elevator which discharges the refuse at a great distance behind the ship, in order to prevent the dredger from getting stuck or being hampered in its movements.

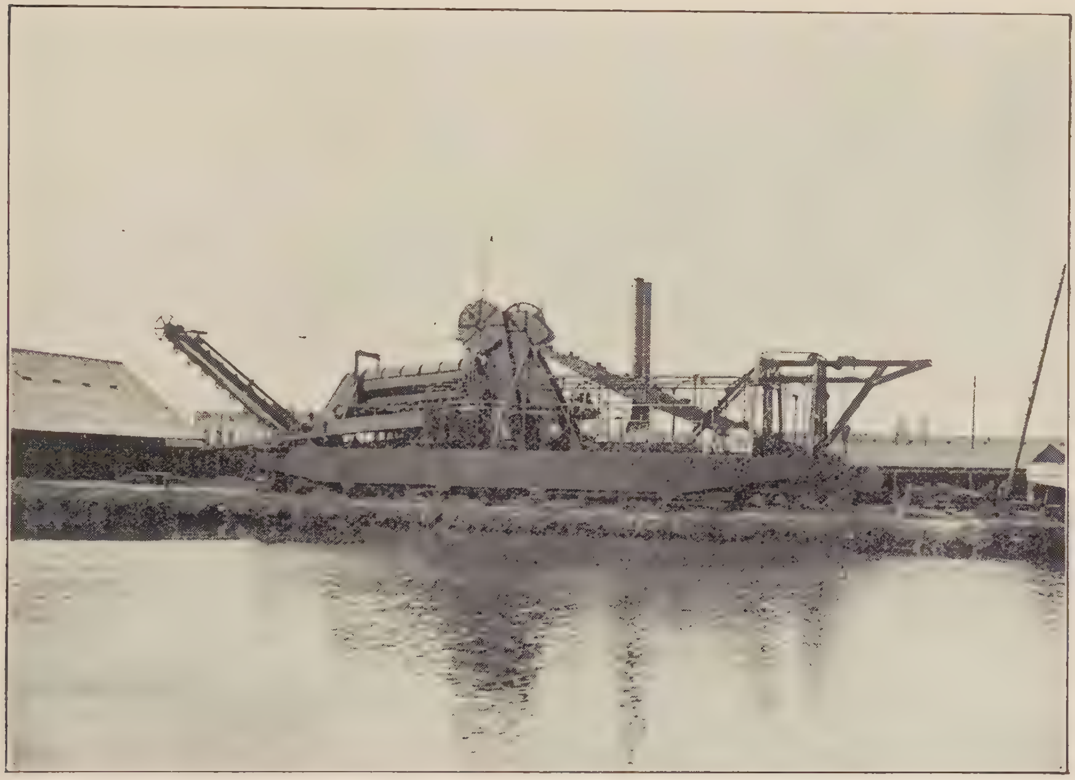


Fig. 64.

Consequently the dredger always works in a forward direction, excavating the ground as it advances, and after extracting the gold deposits the residue behind the vessel.

The gold, mixed with soil and water, drops through the holes on to " transverse tables," which are placed side by side under the rotary screen covering nearly the full width of the vessel. These tables slope from the centre towards the sides of the vessel, and end, both on the starboard and port side, in a " longitudinal shoot " which extends to some metres behind the vessel. The supply to the tables can be regulated by simple revolving shed plates, which are placed under the screen.

The bottom of the tables is provided with coco or felt mats, which are again covered by easily removable, perforated plates with oblong openings. These plates have vertical sides which serve to retard the flow of the mixed soil discharged by the screen. The impediments are placed in such a way that the holes lie behind them, and when the heaviest particles, in this case gold, flow over them, they settle behind them and pass through the holes and into the coco mat.

After being relieved of the gold in this manner the spoil is conveyed by the two longitudinal shoots to the rear of the vessel. In the shoots this *résidu* passes over a layer of mercury which extracts any gold that may still remain. From experience, however, it is found that there is generally very little gold to be found in it.

Most of the gold is found on the first coco mats, close to the screen, owing, probably, to its high specific gravity (19) and the purity in which this metal is found.

The coco mats are daily, or as often as is considered necessary, washed out in a trough of water and mercury, and in this way the mats are cleaned, and at the same time the gold and soil is separated, the mercury absorbing only the metallic gold. By this amalgamating process, *i.e.*, the dissolving of the gold in mercury, the gold is purified, and afterwards recovered by distilling off the mercury.

For the sake of completeness we may add that some gold might be lost owing to some of the spoil remaining in the buckets. To prevent this, the spoil is gathered and conveyed to the suction opening of the water pump, so that finally this also finds its way into the screen.

In America the hexagonal tumbler has been successfully replaced in some cases by an ordinary roller of manganese steel, so that the bucket chain moves more regularly. Because of the small bucket and the consequently small pitch, a roller can be used without any objection (Fig. 65). It would be well to give this roller a trial on larger dredgers for ordinary dredging purposes, because the hexagonal tumbler merely serves as a guide drum, and as such the circular shape would be the right one and the best if other objections can be met. Strong intermediate links will certainly be required in the first place.

The bow and stern chains are also sometimes replaced by spuds, as will be seen when discussing the cutter-suction dredgers.

The constant value of gold, as compared with other metals, may be mentioned as an advantage in drawing up a true working account.

TIN DREDGER

The tin dredger owes its existence both to its low operating expenses as well as to the fact that people had been on the lookout for a long time for an appliance suitable for working ground containing tin, where the usual method could not be applied, as is the case, for instance, in rivers, seas or places adjoining these.

About ten years ago the first trials with tin dredgers were made in New Zealand

and Australia, and these were so satisfactory that at the present time a large number are working successfully even in countries where other methods were used hitherto.

The greater number of these dredgers are operating in the Malay States. For several years two have been working for the Sinkep Tin Co., and the Billiton Co. soon followed their example. It may safely be said that they have already outgrown their earlier childhood, and are still continually being improved, and it is of importance to follow attentively the latest improvements and requirements of these appliances.

Little gold is lost with a gold dredger owing to its high specific gravity, and because the metal is found in a pure state. In the case of tin, however, these two factors are not so favourable, since the specific gravity of tin is only seven compared with nineteen of gold, and as it is not found in so pure a state the tin grains, however small they may be, being enveloped in a layer of earth, which usually penetrates into the pores, the specific gravity of the tin ore is still less.

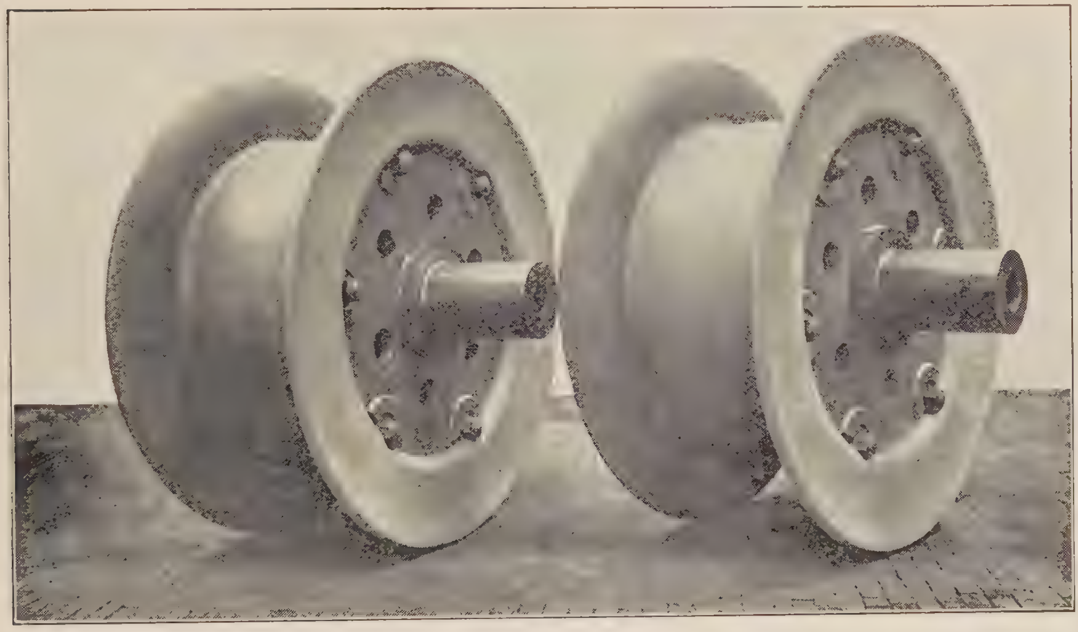


FIG. 65.

Consequently, in tin dredging operations the washing of the tin ore is of great importance. On land this takes place in long wooden shoots, in which ridges or transverse partitions are placed and which serve to impede the flow of the water. The tin grains settle against the latter, and to assist the washing process are continually raked about to rid them of all dirt. When these operations are carried on on board the vessel they are considerably hampered by the pitching and tossing of the boat, and the shoots are of necessity a great deal shorter in length, which is a great disadvantage.

With this explanation it will be clear that the principal thing required of a tin dredger is to save as much tin as possible, or rather to work with the smallest possible loss (Fig. 65A).

When we observe the working of a tin dredger we see that it shows great resemblance to that of a gold dredger. Vessel and dredging plant are the same, while the spoil is also conveyed to a rotary screen. The water for rinsing is, however, pumped with much greater force over the full length of the screen, and it is advisable to prevent the spoil

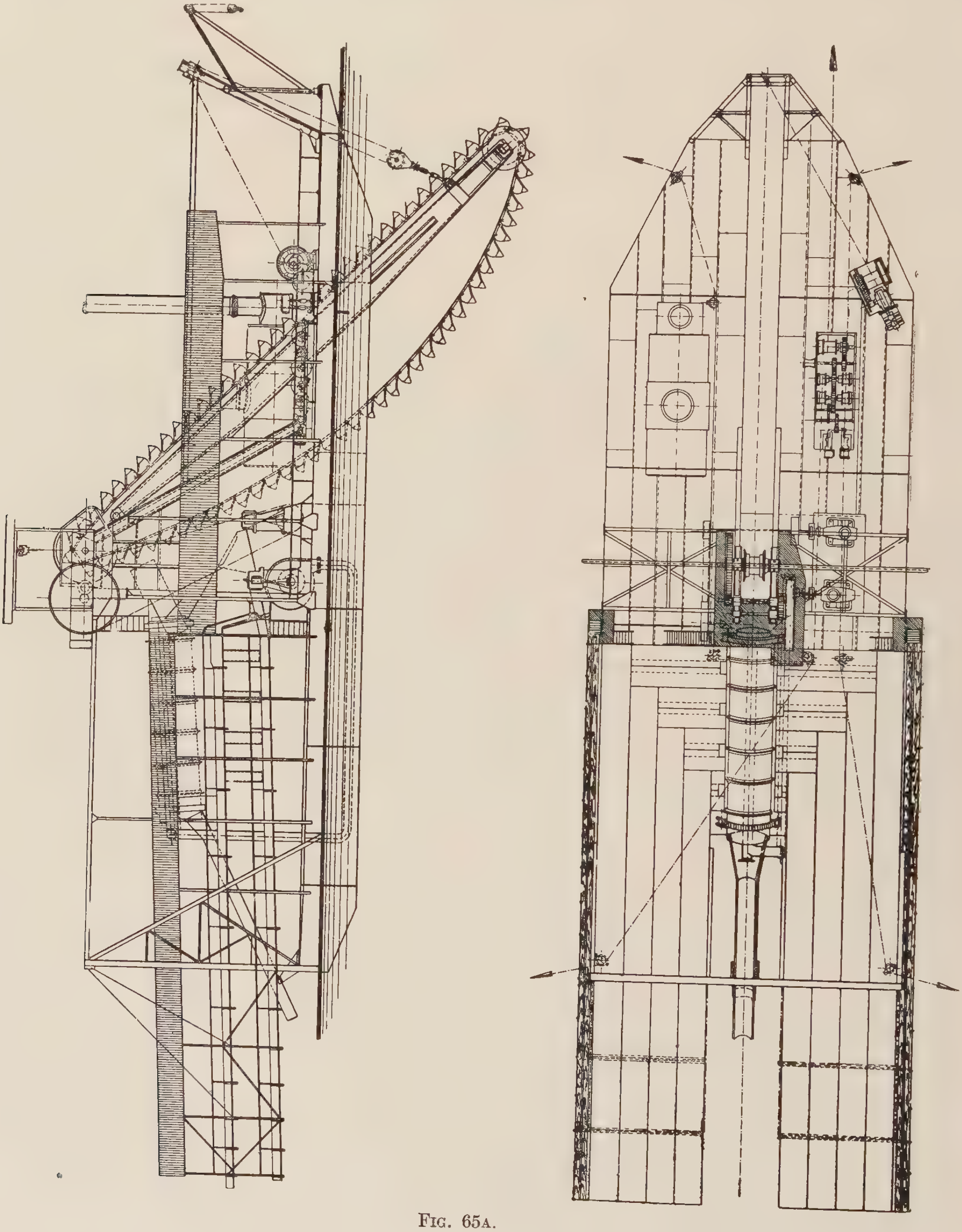


FIG. 65A.

from flowing down too rapidly into the stone shoot (Fig. 66), which can be done, for example, by leading a mobile and powerful jet of water into the lower end of the screen. One of the deck crew must devote his entire attention to the contents of the screen, and direct the jet of water to the spot where it is wanted most. In this way the tin ore is detached from the soil, and at the same time prevented from flowing off as refuse with those pieces of clay called clay balls. Even then much ore is lost through these clay balls, and this is a problem which demands further investigation.

If desired an elevator may be mounted on the stern of the vessel, although on the whole the longitudinal shoots convey the refuse far enough behind the vessel.

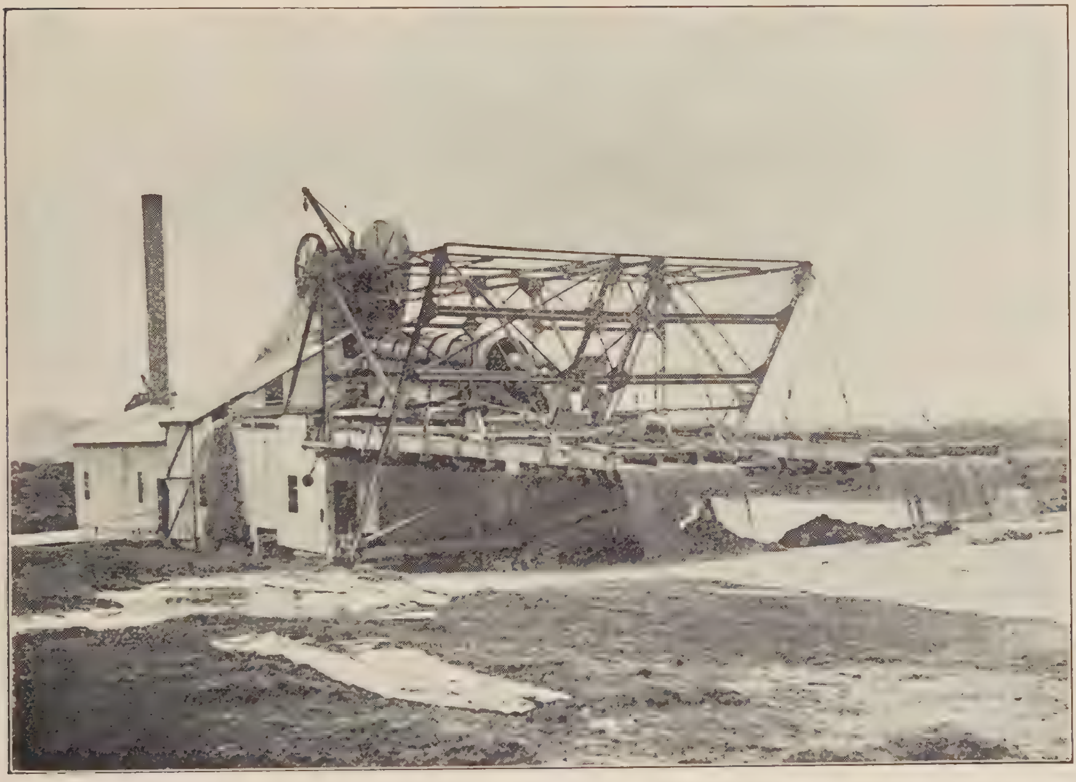


Fig. 66.

The tin ore, mixed with fine particles of soil, falls through the screen on four or five "transverse tables," while several longitudinal tables, placed at right angles with the latter, convey the spoil to the stern and drop it there with the smallest possible loss (Fig. 67).

Both on the starboard and port side there is a set of sloping transverse and longitudinal tables, the spoil from which may be conveyed either to starboard or port at will.

The bottoms of the longitudinal tables are covered with wood, which causes the ore to be washed in some degree. Ridges are placed at distances of about 1½ metres apart and consist of piled-up square steel bars of about 30 to 35 millimetres in width.

Thus they can easily be arranged the required height, while the work is in progress, by adding a bar as the ore piles up in front of them. Wooden ridges should be avoided, as these get lost too easily, owing to the strong current in the shoots. Just as with the washing process ashore, the ore which is piled up against the ridges is rinsed by continual raking.

The longitudinal tables on the first dredgers were small, and the work had to be suspended as soon as sufficient ore had accumulated in front of the ridges. The ore was then rinsed once more and removed, after which the work could be continued.

The later dredgers, which have already attained a width of over 15 and a length of about 50 metres, have all four or five longitudinal tables on each side. These longitudinal tables can be closed near the transverse table so that the final washing can take place alternately in either of these tables, while the dredger keeps on working.

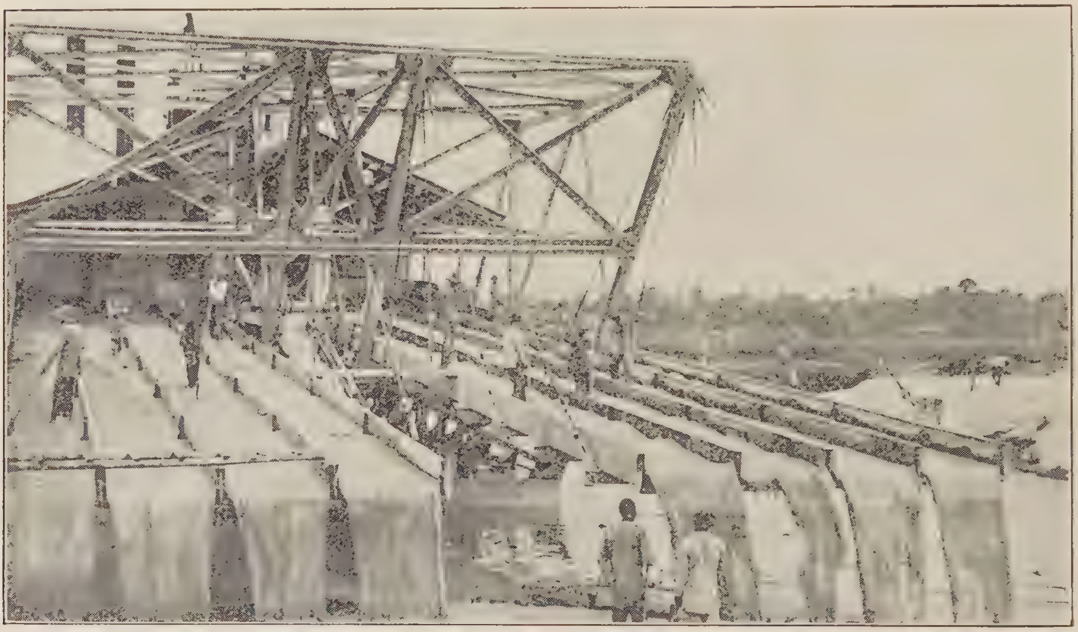


Fig. 67.

In order to spread the spoil containing the ore more effectually over the tables, two complete sets of tables are sometimes placed on top of each other, in which case the spoil can be divided by means of sliding shutters over both tables.

The width of each shoot is about 1·20 metres, the length rather more than 30 metres, while the inclination is about 1 in 24. The weight of the tables increases considerably when the work is in progress, a fact which should be taken into account when constructing them.

The dredgers are also equipped with an appliance to receive the spoil that is spilled from the buckets; on the deck behind the well a double transverse table is placed, so that one of these can be subjected to a final washing, while the other is in use. With two sets of tables the spilled material is straightway conveyed to the lower one.

Though the tin dredger has been fairly described above, the following particulars may be added.

The capacity of the buckets varies from 140 to upwards of 300 litres. Without much ore being lost the first screen has an output of 80 cubic metres of soil per hour. This screen has a diameter of 1·20 metres, a length of 7·50 metres, and an inclination of about 1 in 10 ; the number of revolutions was 8 to 12 per minute.

A bucket of great capacity is useful so long as the earth which covers the layer of tin ore only has to be removed ; as soon, however, as the soil containing ore is dredged, the main thing to be considered is that no larger quantities should be dredged than the screen can cope with. When this stage is reached the utmost attention is demanded of the dredger master, who has to see to it that the buckets are filled regularly and that a steady supply to the screen is secured. The number of buckets per minute varies from fifteen to twenty-two according to circumstances.

The revolving screen is driven either by the main engine of the dredger, the rinsing engine, or an entirely independent engine. In many cases the main engine is used, although it would seem an obvious advantage if the number of revolutions of the screen could be regulated independently with respect to the bucket chain.

The transmission of the engine to the screen demands much consideration, and it may be safely asserted that the best method has still to be discovered.

Formerly the transmission took place through a Gall's chain, which was placed round the rotary screen and driven directly from the engine or from a countershaft. It is advisable to mount the screen on a bed plate entirely independent of that of the main framing to prevent the vibrations of the latter being transmitted to the screen.

If another transmission system is used this fact should be taken into account.

The screen may also be driven through the highest or the two highest travelling rollers, but this system has its drawbacks. If the screen is driven by one roller only, there is trouble from slipping ; if by two, great wear is caused by the unequal wear of the two rollers.

Yet another way is to rest the screen with its lower side on a roller and to drive it through the latter. Owing to the greater pressure exercised on this roller there is less slipping. In this case the screen has a guide-roller on each side. This method of construction has been applied to many modern dredgers.

With all these methods it must not be forgotten that the parts that are exposed to great wear and tear should be easily renewable.

For the raking and washing of the ore many hands are required, and consequently means have been sought to do this work mechanically, but although several trials have been made with mechanical rakes, one cannot say that they have led to any contrivance that can be recommended.

Besides the centrifugal pump for the screen there is a similar plant on board which has become indispensable, since it has been found necessary to pump the water into the screens with great force. This is a pump which supplies water for the various rinsing tables, the ballast tanks, for washing the deck, and, if required, can also supply the circulating water for the condenser and for whatever other purpose water may be needed.

All that has been mentioned before about dredging plants in general also holds good in respect to the dredging plant of the tin dredger.

In the latest dredgers the bucket chain is close connected and made entirely of "Era" manganese steel; whilst the pin, which extends the entire width from one side to the other, is of toughened nickel-chrome-steel, the diameter of this pin exceeding the maximum of that of which "Era" manganese steel pins are manufactured. This maximum is about 93 millimetres, whereas the diameter of the pin under discussion is at least 125 millimetres (Fig. 68).

That a close-connected bucket chain is preferred for tin dredgers will be obvious to everybody, for by this arrangement the screens can be fed regularly with small quantities of material.

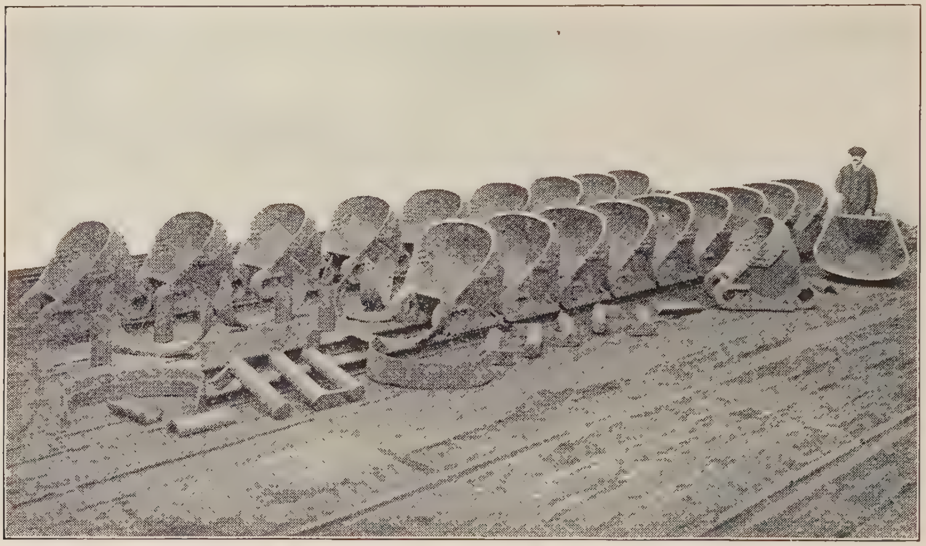


Fig. 68.

It is certainly worth while to observe this method of bucket construction with attention, as it possesses many good qualities which are still wanting in modern dredgers.

With this method of construction it is possible to extend the bearing surface of the pentagonal tumbler to the centre, that is, right under the centre line of the bucket pin. Slipping of the tumbler has now become well-nigh impossible, and at the same time the chain fits closer round the tumbler. Instead of a pentagonal tumbler, a hexagonal one may even now be used (Fig. 69).

It cannot be denied that the bucket chain of the tin dredgers has reached a state of greater perfection than that of the ordinary mud dredger, and that the baskets move more smoothly and noiselessly round the pentagonal tumbler, which still leaves much to be desired in the case of the ordinary dredger. Fig. 70 shows a first attempt made in this direction on the mud dredger, an attempt which was crowned with success although very rocky soil had to be excavated. Between the buckets small tables had been placed to protect the buckets from being damaged by large dredged stones on leaving the hexagonal tumbler.

Instead of the hexagonal tumbler a round drum is preferred which can be used because of the fairly short pitch.

Generally a central winch is used for working the bow- and stern-winches, sometimes also those of the bucket chain and bow cable. Apart from the fact that this construction is much cheaper, it also saves several hands. As it is customary, however, for the dredger master to attend to the ladder and bow cable winches it seems advisable to work only the bow and the stern cables by means of the central winch, the more so as these demand almost the entire attention of one man.

On the forecastle a powerful hoisting gear for removing tree trunks and other heavy objects, found in the dredging ground should be available both on starboard and port. These cranes should serve at the same time for the replacing of the bottom tumbler and for weighing the anchors.

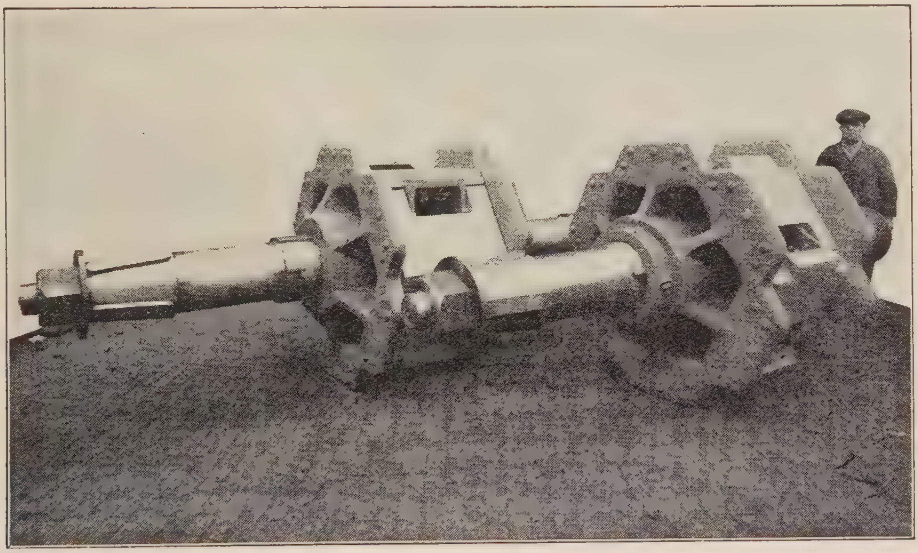


Fig. 69.

Awnings of corrugated iron cover the deck ; if desired the rain water may be led to the fresh-water tanks.

Condenser pipes of large diameter (50 millimetres) are used, as the ordinary narrow pipes soon get choked in the tropics.

Although it is not improbable that in the near future the internal combustion motor or electricity may be used as the driving power, steam power has been generally used till now, being generated by burning coal, crude oil or wood.

Dredgers driven by electricity are only found in places where the current can be supplied by a central power station. The capacity of these dredgers, too, has been largely increased of late years, and recently two dredgers have been built for the Billiton Co., which are electrically driven from their own stationary power station on the shore.

The principal dimensions of these vessels are :

Length	46·00 metres.
Width	15·25 metres.
Depth	2·60 metres.

The screen has a diameter of about 2·20 metres and a length of 10 metres, and is driven on the one dredger by two top rollers, on the other by one bottom roller.

The bucket chain is close connected, and the bucket capacity 320 litres. At the top the buckets move round a hexagonal tumbler, and at the lower end of the ladder round a roller. There are two sets of washing tables, one above the other, each set containing five transverse and five longitudinal tables, on both starboard and port sides.

Of late an entirely new method for washing the ore has come into use, a method which greatly reduces the loss of the fine ore.

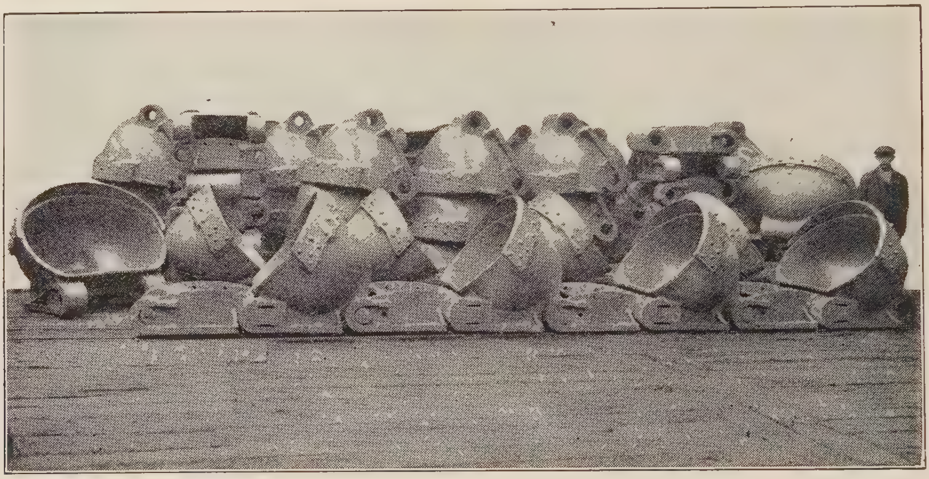


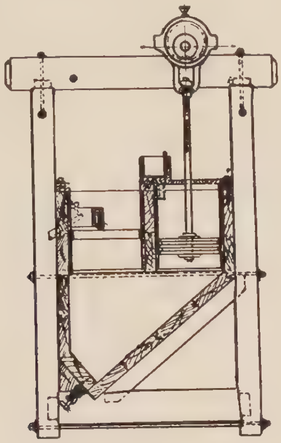
Fig. 70.

Instead of leading the spoil over the longitudinal tables, it passes a series of jigs or " shake tanks " (Fig. 70A). The tanks themselves do not shake, however, but the water inside them is kept in perpetual agitation by a slight up-and-down motion of a piston. The piston is so constructed that the water is forced away when it moves down, but there is no suction on its upward movement, the sides being provided with hanging rubber valves.

On the other side of the tank is a perforated plate, to which a heavy rinsing bed is attached, and over which the spoil passes after leaving the screen. By repeatedly forcing the water through this bed the lighter materials are driven out of it and only the tin ore passes through into the tank, where it settles, and from which it is afterwards removed.

The transverse table, which feeds the jig both on the starboard and port sides, is equipped with square pyramidal storeys, over which a stream of water passes. The spoil from the screen passes first of all over this stream and the heavier particles settle into the above-mentioned storeys, whence they are led through the jigs above-mentioned.

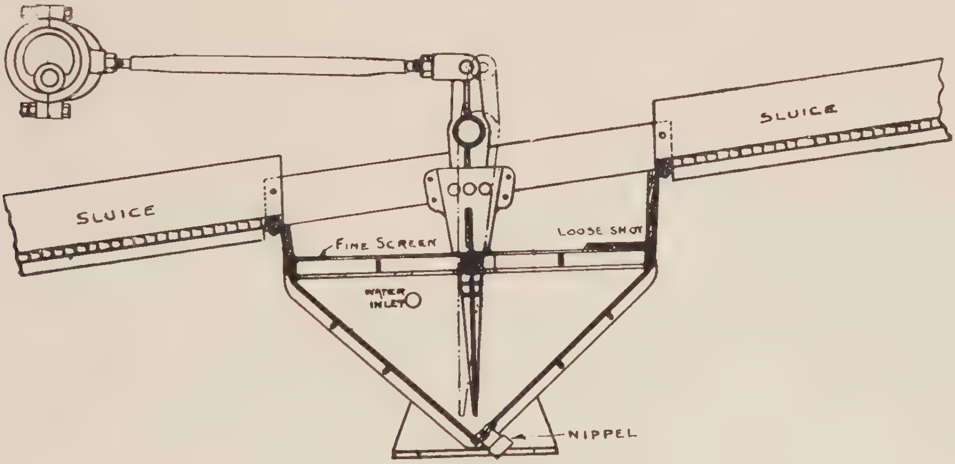
The superfluous refuse is conveyed by a single longitudinal shoot on the starboard and port sides to a convenient distance behind the vessel.



HARZ JIG

Fig. 70a.

This is an entirely new method, and is working very satisfactorily. The jig described above is the Harz jig, while Fig. 70b shows the Neill jig. With the latter the washing is effected by a fan-like movement.



NEILL JIG

Fig. 70b.

Having now come to the end of our survey of bucket-ladder dredgers it may be well to point out that these machines have to perform very rough and heavy work, so that the construction has to be very strong if one does not want to experience to one's own detriment what an English expert has expressed so pointedly:

"Inferior machinery and parts mean continual stoppage for repairs."

PART II

SUCTION AND FORCE-PUMP DREDGERS

The idea of dredging ground by means of centrifugal pumps originated in England and France. According to Charles Prelini, we owe the first application of it about the year 1864, to a Frenchman, M. Bazin. In Mr. J. J. Webster's "Dredging Operations and Appliances," Mr. Woodford is mentioned as one of the first who used a pump for this purpose. The two methods differ so much, however, that we can safely adjudge each a portion of the credit.

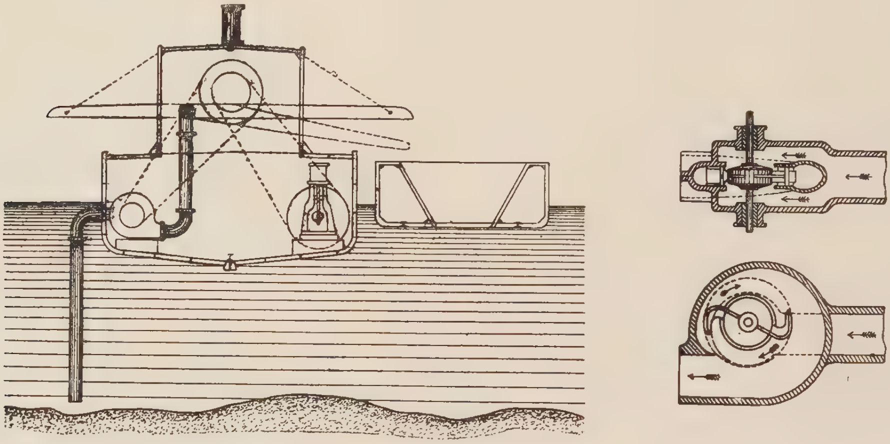


Fig. 71.

THE BAZIN SAND PUMP

(Fig. 71)

Originally this was a centrifugal pump with pipes of 25 to 30 centimetres diameter. Originally the disk was four-bladed and had a diameter of about 60 centimetres, and revolved at the rate of 350 revolutions per minute. Two of the disk blades having been broken off accidentally, it was found that the pump worked much more satisfactorily without them, so that two-bladed disks were used ever afterwards.

It is said that the most satisfactory results were obtained in gravel or sand, the proportion of water to sand being about five to one.

At one time this pump was used at the Suez Canal works.

In 1867 Bazin sent a model of a dredger to the Paris Exhibition, a dredger which he considered specially adapted for the dredging of light soils. Of this suction dredger a description was given by M. Marcaire in the *Revue Industrielle* for July 28th, 1875, a translation of which, by M. J. J. Brutel de la Rivière, has appeared in the *Tijdschrift van het Koninklijk Instituut van Ingenieurs* for the year 1876–1877.

A sketch belonging to this article has been reproduced in Fig. 72. In this article it is stated :

> " That this dredger can suck 3,000 cubic metres of sand per day from a depth of 8 to 12 metres.
>
> " The working is explained as being the result of a constant water pressure, and a continual drawing up of sand by means of centrifugal pumps ; these raise the sand and the mud through pipes of 25 centimetres in diameter, which pass through the hull of the vessel to 2 metres below the level of the water. Thus a difference in levels is obtained which produces moving power, so that a swift current, which in its upward movement carries along a considerable quantity of sand and mud. The spoil is conveyed by two or four pipes towards the pumps which discharge it into the shoots."

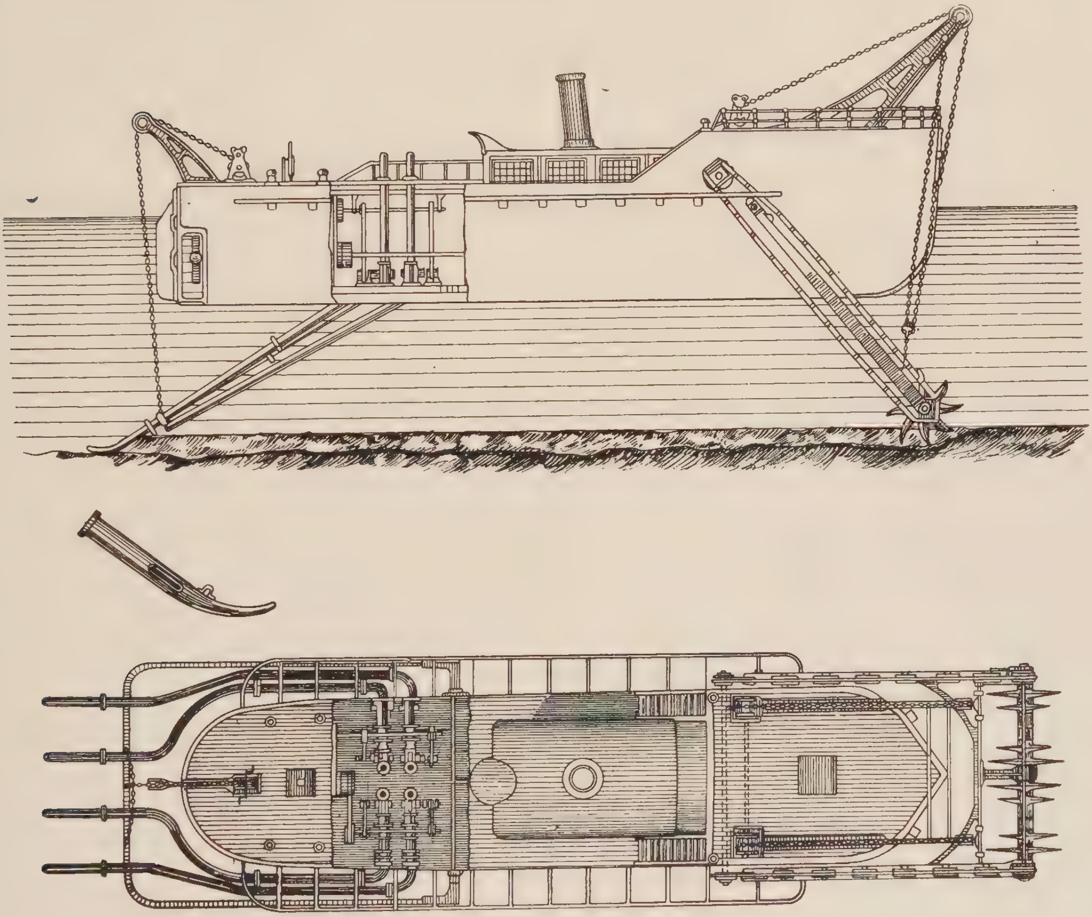


Fig. 72.

The following advantages are claimed :

1. A greater dredging depth can be attained than by using bucket-ladder dredgers.
2. Work in a stronger swell is possible.

3. There is less danger of damaging masonry.
4. Work in a limited space is rendered possible.
5. Shifting the position of the vessel becomes unnecessary.
6. Less inconvenience is suffered by other ships.

A list included in the article proves, moreover, that this way of working is cheaper than when using a bucket-ladder dredger, and that more work is done in a given time.

As can be seen from the sketch, the dredging ground is first raked loose with scrapers, and the vessel is moved forward by means of the propeller while dredging.

It is very singular that the satisfactory results obtained by this method are attributed to the fact that there is a difference of 2 metres in level between that of the water and the suction pipe within the ship, while the suction power of the pump is never mentioned.

WOODFORD'S SAND PUMP

This pump consisted of a horizontal disk with two or more blades, which moved in a case, somewhat similar to the ordinary centrifugal pump. The disk was keyed to a vertical shaft, which was driven by a portable engine, a belt and a set of bevel-gear wheels.

The pump rested on the ground, the suction pipe being so arranged that water was drawn in along with the sand ; the proportions of the two being regulated to suit the size of the sand grain.

The discharge pipe was rectangular to the pump body and carried the vertical shaft. The whole apparatus being adjustable to suit different depths of water. This arrangement has been used with advantage on various works.

BURT & FREEMAN'S SAND PUMP

This pump is a modification of the Woodford pump, and was used for the first time in the construction of the Amsterdam Ship Canal, executed by the above-mentioned English contractors.

The earth that was excavated had to be deposited on the banks, in many places fairly close to the dredgers, and the contractors decided to force the spoil direct to the depositing ground by means of the pump if this should prove more economical (Fig. 73).

For this purpose the soil, after being raised by the buckets, was led into a vertical chamber, attached to the outside of the bucket dredger near the shoot, so that the dredgings were discharged into it. The pump drew up the water on the bottom of this chamber, which reached into the water. Thus the body of the pump had a suction opening on each side, so that the spoil entered at the top and the water was drawn in at the bottom, the mixture of sand and water being discharged by the revolving disk into floating pipes and conveyed to the depositing ground.

The disk was rather more than 1 metre in diameter and made 230 revolutions per minute. It was driven by the main engine by means of a belt and a set of bevel gears. The disk shaft was supported by a steel pivot, and it was this point especially which required great care, owing to the wear and tear to which it was exposed.

In some cases the discharge pipe was 100 metres long, and discharged the material $2\frac{1}{2}$ metres above the water-level.

Each dredger and pump had a discharging capacity of 100 cubic metres per hour.

The discharge pipes were 38 centimetres in diameter, and were built up of strips of wood; the staves were kept together like those of a barrel, by iron hoops. They were kept afloat by attaching them on each side to a floating beam. Each pipe was 6 metres long, and they were jointed together at first with linen and afterwards with leathern hinges, which were secured to the pipes by means of straps. Afterwards dredgers were built with a chamber inside the ship.

As a rule these machines were used near the depositing ground. The material which had been dredged elsewhere was discharged by means of hopper barges near the pump dredger; the latter dredged it again and conveyed it to the depositing ground.

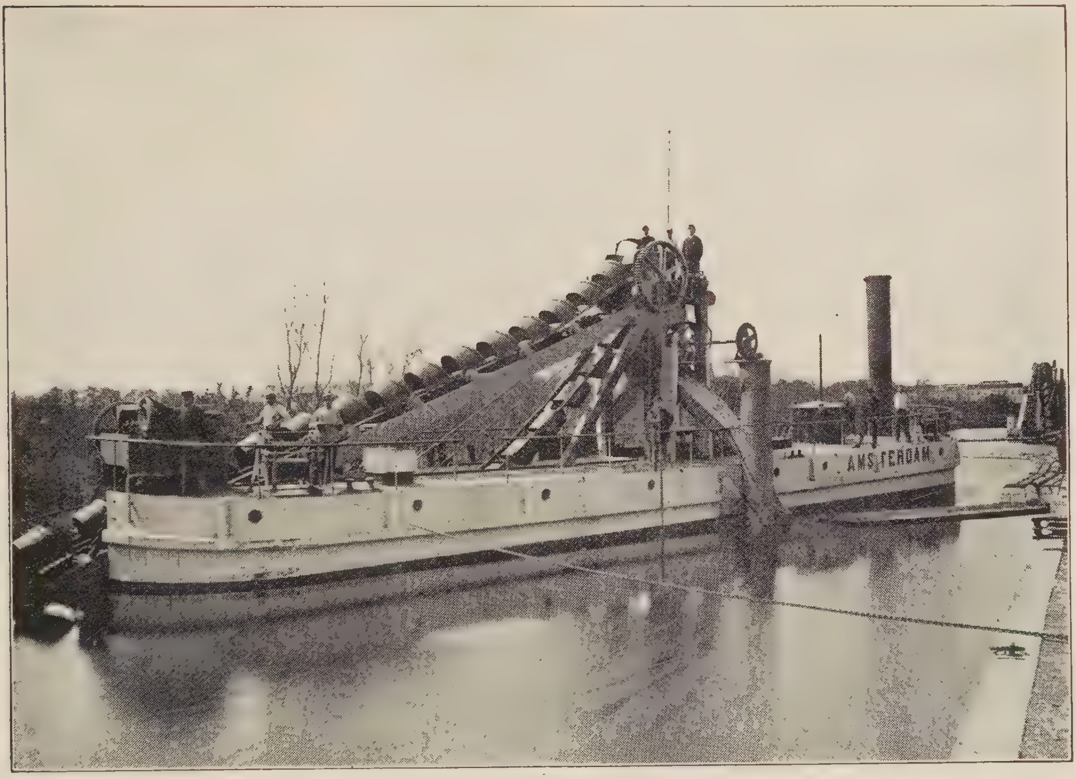


Fig. 73.

These pump dredgers were for a considerable time extensively used, but since 1887 they have been ousted by more modern appliances.

HUTTON PUMP

Another modification of the Woodford pump is the Hutton pump, which has likewise been used successfully on the works of the North Sea Canal. It was built by Mr. Darnton Hutton, and became the precursor of the Dutch hopper-suction dredgers.

A sketch of this pump is shown in Fig. 74. The principal alterations introduced into the Woodford pump were :

1. The suction pipe.
2. The open two-bladed disk.

This pump served to dredge sand and to discharge it into barges. Figs. 75 and 76 give a faithful representation of the appliance.

The vessel was about 20 metres long and 6 metres wide ; it was built of wood, and was shaped like a Scheveningen fishing-boat (*bom*). In the ship were a flue boiler and a steam engine of 150 I.H.P. with one inclined cylinder and a surface condenser. The sand pump was driven by the engine by means of belts and bevel gearing ; a chain drum, which served to raise the suction pipe, was also driven by gearing. Both pump and suction pipe were mounted in a framing, and the latter could be lowered by means of a brake.

The vessel was equipped with a bow and stern anchor. When working the pump was entirely submerged, without doubt an ideal way to prevent air from being drawn in through the gland.

The discharge pipe ended in a T-piece, which was attached to a leather bag with a short pipe supported by small gins. Hopper barges, which could be loaded by means of these pipes, were moored on both sides of the dredger.

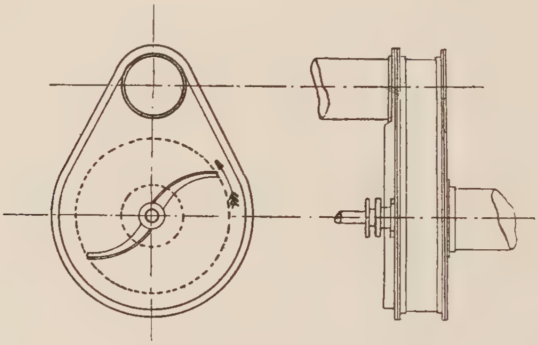


Fig. 74.

The satisfactory results depended on the fact that the sand could be readily drawn up. Everybody will have noticed that when trying to dig a pit in the sands close to the sea, the wet sand will keep on flowing, no matter how deep one goes, and that it is perfectly useless to go on digging. In streaming water such a pit will be filled even more quickly, and it is obvious that once a pit has been begun an enormous quantity of sand can be drawn up by sinking the suction pipe deeper and deeper. The beginning is, consequently, the most difficult part of the proceedings ; for we should not forget that the upper layer of the sand usually consists of a heavy shale, a fact which can be easily ascertained by means of borings, or on sand banks that have run dry.

If the suction pipe is merely let down on to the sand, only water is drawn in, and sand is only raised when the pipe is forced into the sand by shortening the bow chain.

Nor can all kinds of sand be raised by means of a suction pump ; sometimes the sand contains elements such as mica, which cause it to cohere to such an extent that the desired pit cannot be made, and only the sand near the opening of the pit is raised. In Holland, however, this does not occur.

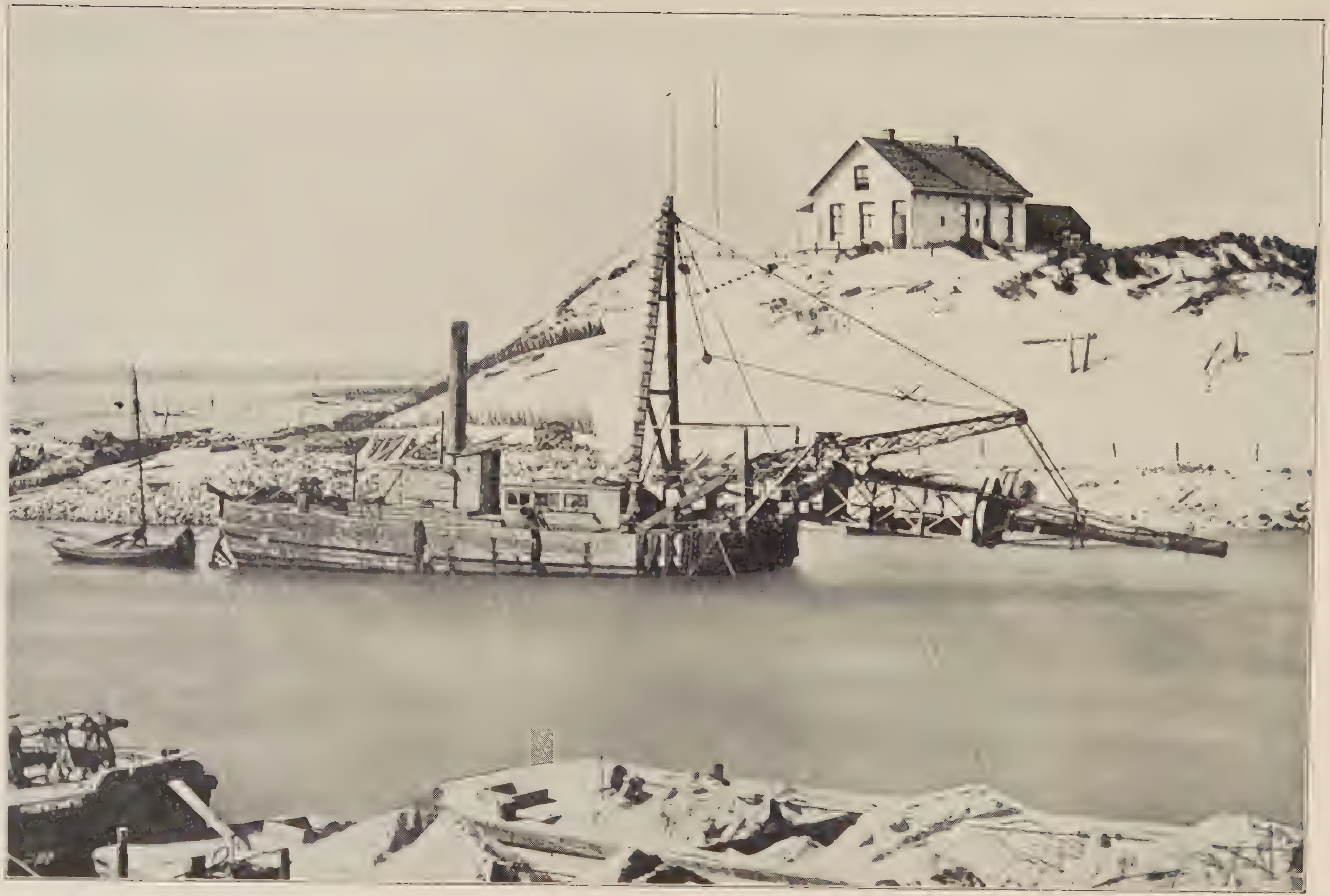


FIG. 75.

These dredgers were used with very satisfactory results on the above-mentioned work, as appears from the fact that in 1876 no fewer than seven were operating there. Each of these raised 500 to 600 cubic metres of sand per day.

Afterwards these sand-pump dredgers were sold, and partly became the property of the Dutch firm of K. L. Kalis Wzn., who used them occasionally even as late as 1892.

From the above it is clear that the English introduced the suction dredgers into Holland; but from that moment the Dutch have contributed much to their improvement, and it is a curious fact that it was only after this type had been improved in Holland, and was being used on a larger scale, that the attention of other countries was drawn to it. Amongst these were the Melbourne Harbour Commission, the Cape Government and the French Government, the latter employing it on the works at Dunkirk and Bordeaux. Sometimes the type is even described under the name of the "Dutch dredger": but, as shown above, this credit should not entirely be given to the Dutch.

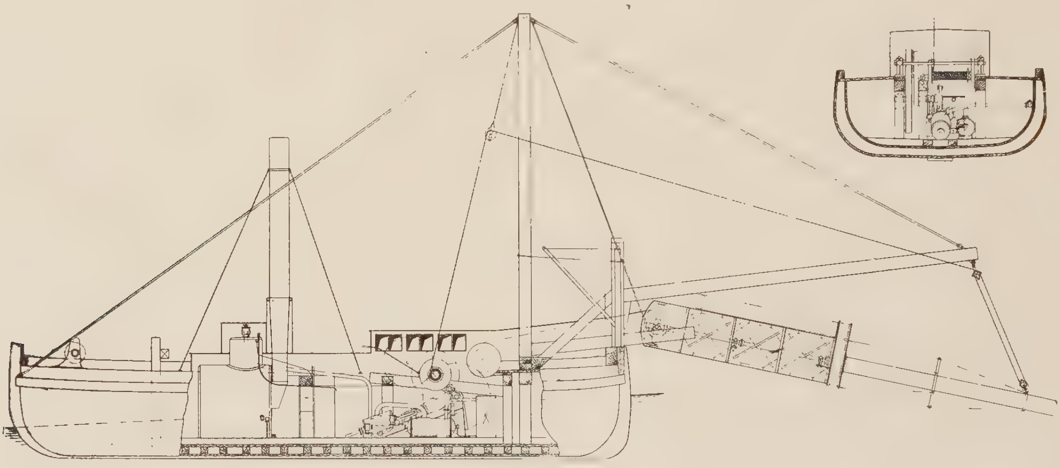


FIG. 76.

THE FIRST DUTCH SUCTION-PUMP DREDGERS

We now come to the period when the improved form of the suction dredger had come into Dutch hands, and was rendering eminent service in the construction of the waterway, the *Nieuwe Waterweg*, from Rotterdam to the North Sea.

The *Tijdschrift van het Koninklijk Instituut van Ingenieurs* for September 6th, 1884, contains an important treatise, in which Ir. W. F. Leemans described the first use of the Dutch suction dredgers, and in which the following is stated:—

"In the year 1878 there were working in the above-mentioned place an ordinary Hutton pump dredger and an improved system, called *Adam I.*, built by the firm of I. and K. Smit from Kinderdijk, on behalf of Messrs. A. Vermaes, P. A. Bos and A. Volker Lzn., contractors for this work."

"ADAM I"

The shape of the vessel had been greatly improved, and had become similar in form to that of an ordinary sea-going ship.

The suction pipe was placed amidships in a well, while the sand pump had been placed inside the ship with the suction opening against the back wall of the well.

The suction pipe was jointed to a short straight mouthpiece by means of a leather bag, which was provided on the inside with an iron spiral to avoid choking. At this end it was hung by two short chains, while the other end could be raised or lowered by means of a chain, for which purpose a drum was mounted on the anchor winch.

The engine was a vertical compound, which could drive either the pump disk or the propeller, by means of simple gearing.

The propeller was driven direct, the disk by means of a toothed gear transmission.

The sand pump had originally the same shape as that of the Hutton dredger ; it was, however, soon improved by mounting a cornerpiece (Fig. 77). The discharge pipe was no longer rectangular, but conveyed the spoil direct to the barges moored alongside.

Like the Hutton pump, this dredger could continue its work in a swell of about 45 c.m. ; if the swell grew stronger the barges alongside caused too much trouble.

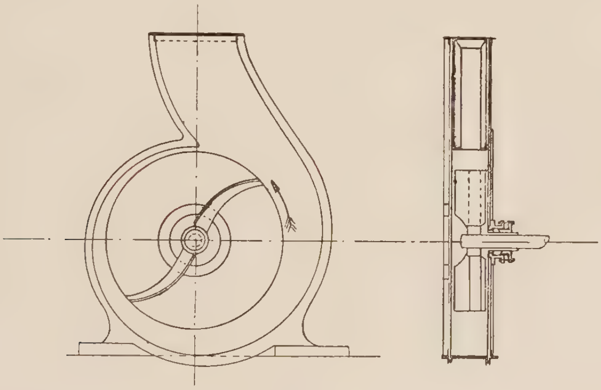


Fig. 77.

"ADAM II"

When the works on the Rotterdam Waterway were nearing the sea, the need was felt for a vessel that could work in a strong swell; hence the above-mentioned contractors had a dredger constructed that carried its own hold, so that it was no longer necessary to convey the dredged material to barges moored alongside, but could be deposited in the vessel itself (Fig. 78).

Thus, in 1878, the first "self-loading hopper dredger," called *Adam II.*, was constructed for the same firm. It was built in the same shipyard as the *Adam I.*, so that for this dredger also credit must be given to the firm of Messrs. Vermaes c.s.

The *Adam II.* could work without difficulty in a swell of 65 centimetres. The vessel was 34 metres in length, 7·80 metres wide, and 3 metres deep. On each side of the well a hold was built, and the two holds had a total capacity of 174 cubic metres ; when fully loaded the draught was nearly 3 metres ; the engine developed 175 I.H.P.

When the vessel was empty the suction opening of the sand pump lay nearly above the water level to make the renewal of the leather bag possible. The suction pipe was 9·80 metres in length; two cross bars, placed across the suction inlet, prevented pieces of wood, etc., being drawn into it.

To protect the pipe when in a slanting position, and prevent it being damaged by the bottom of the ship, a teak-wood guide beam, supported by the sides of the well, was attached to it.

The dredged material was discharged by a U-shaped discharge pipe into the two holds, in which the sand settled while the water flowed off again over the gangways (Fig. 79).

Over the entire length of the discharge pipes valves could be opened so that the sand could be conveyed to any place in the holds, and the vessel be evenly loaded.

Both holds were, like the hopper barges, equipped with doors which were closed simultaneously by means of hand winches, and, by removing a cotter, each door could be opened separately, the chain having been first loosened.

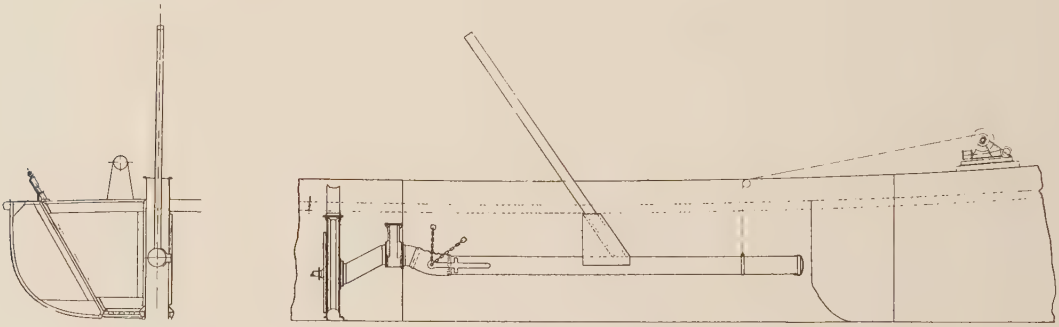


Fig. 78.

As soon as the holds were full the suction pipe was drawn up, while the pump kept on working for a moment to prevent the pipe getting stuck in the sand.

Disconnecting the pump and putting the propeller into gear took place simultaneously with the weighing of the bow anchor; after which the vessel was ready to take the load out to sea and discharge it. The filling of the holds took about forty-five minutes; thus 580 cubic metres of sand were shifted per day in about four loads. In 1879 there were 165 days on which the work on the Rotterdam Waterway could be continued.

"ADAM III"

It was soon realised that the self-loading hopper was the ideal vessel for finishing the construction of the mouth of the Rotterdam Waterway, and in his description Ir. W. F. Leemans renders due honour to these suction dredgers, by declaring that they played an important part in the improvement of this harbour mouth.

In 1880 the *Adam III.*, a vessel of still greater dimensions, followed. The length of this vessel was 42 metres, the width 8·30 metres, the depth 3·35 metres, and the capacity of the hold 214 cubic metres. The engine developed over 200 I.H.P.

"ADAM IV" AND "MAASMOND"

An important improvement was introduced by Messrs. Vermaes, Volker and Bos in the next two hoppers, which were built in 1881, one by J. and K. Smit and the other by L. Smit and Zoon, at Kinderdijk (Fig. 80).

The suction pipe was no longer placed in the well, but against the side of the ship. In the first place, the well could now be dispensed with, in consequence of which a better hold was obtained, and in the second place breaking of the suction pipe was largely prevented, as it stood less chance of being damaged by the hull of the vessel when working in a swell.

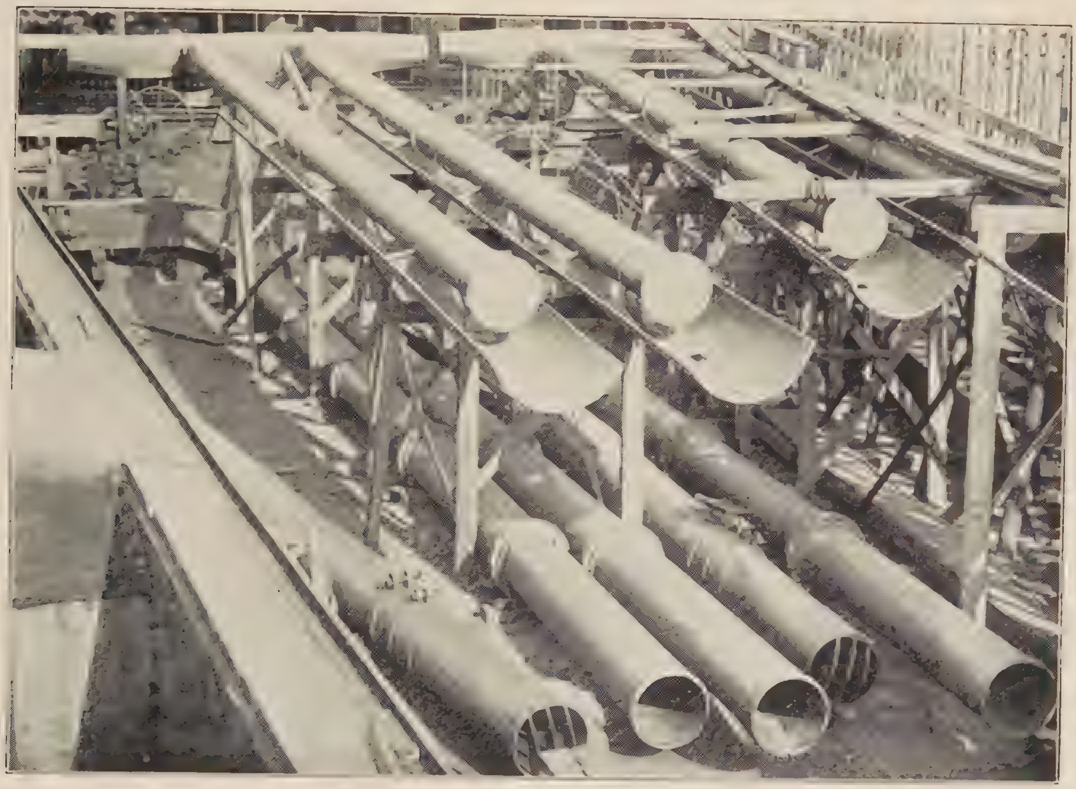


Fig. 79.

Against the side of the vessel a cast-iron bed piece was attached, to which the suction pipe was jointed in the usual way by means of a leather bag. The spiral in the bag had been replaced by three or four oval iron rings, which had proved more easily renewable because they were within better reach. Fig. 81 shows the sand pump with suction and discharge pipes being fitted up in the shipyard.

The suction depth was 10 to 11 metres below the water level, while the dredgers could work in a swell of 0·90 metre.

A great many dredgers of this type were afterwards built to the order of the above gentlemen and others, as may be seen from the following list. Special mention should be made of the hopper *Amsterdam*, which had a hold of 300 cubic metres, and was built by the firm of L. Smit and Zoon for the firm of Kalis, and used on the works at Ymuiden in 1882.

On this vessel both the pump and the propeller were driven direct by the engine. In this instance toothed-gear transmission was not used as had been the practice hitherto, in the first place because previous to that time slow-speed engines had been the practice, and, in the second place, it was feared that a sudden stoppage of the pump disk might have a harmful effect on a high-speed engine.

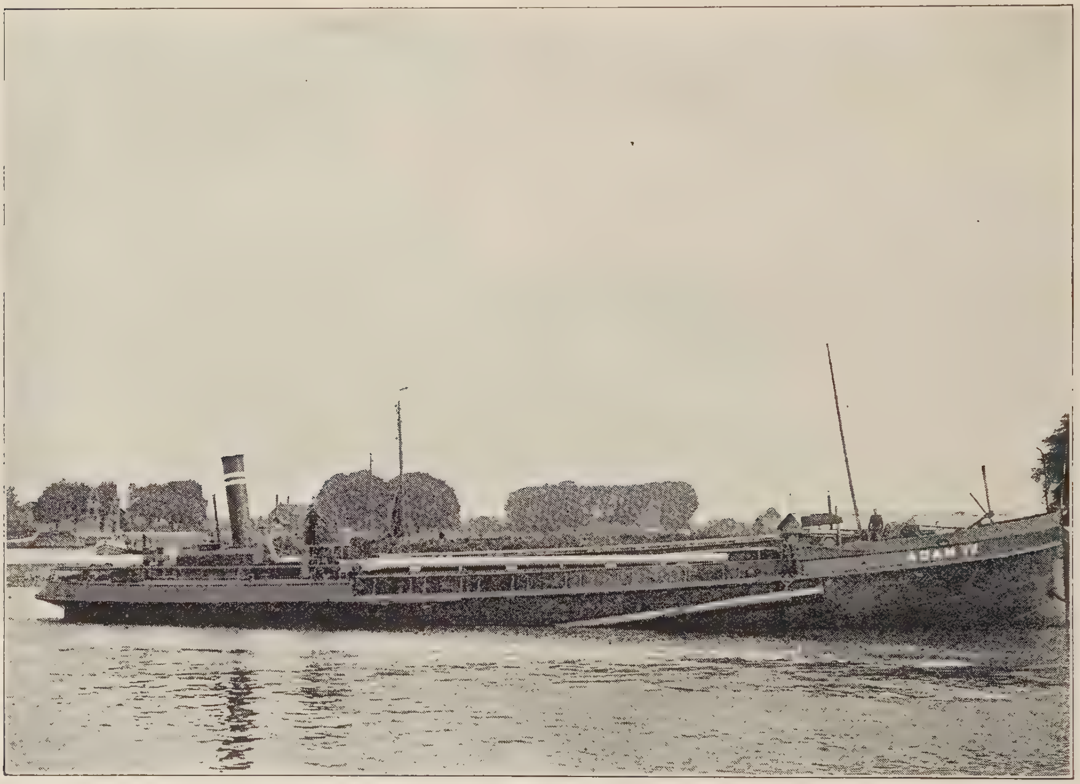


Fig. 80.

In the above-mentioned dredgers the self-loading hoppers had made a glorious appearance, and had proved their usefulness in completing and keeping up harbour works in the mouths of rivers, as well as on the coast ; so much so that in 1882 many new suction dredgers were built, which were in turn soon followed by others of even larger dimensions.

From the foregoing it will be clearly evident that the credit of this invention, as well as the first application of it, is due to Messrs. Vermaes, Volker and Bos, while the firm of I. and K. Smit were the first builders. They were soon followed by L. Smit and Zoon, as may be seen from the list on the next page, which gives some data regarding the earlier suction dredgers built in Holland previous to 1882.

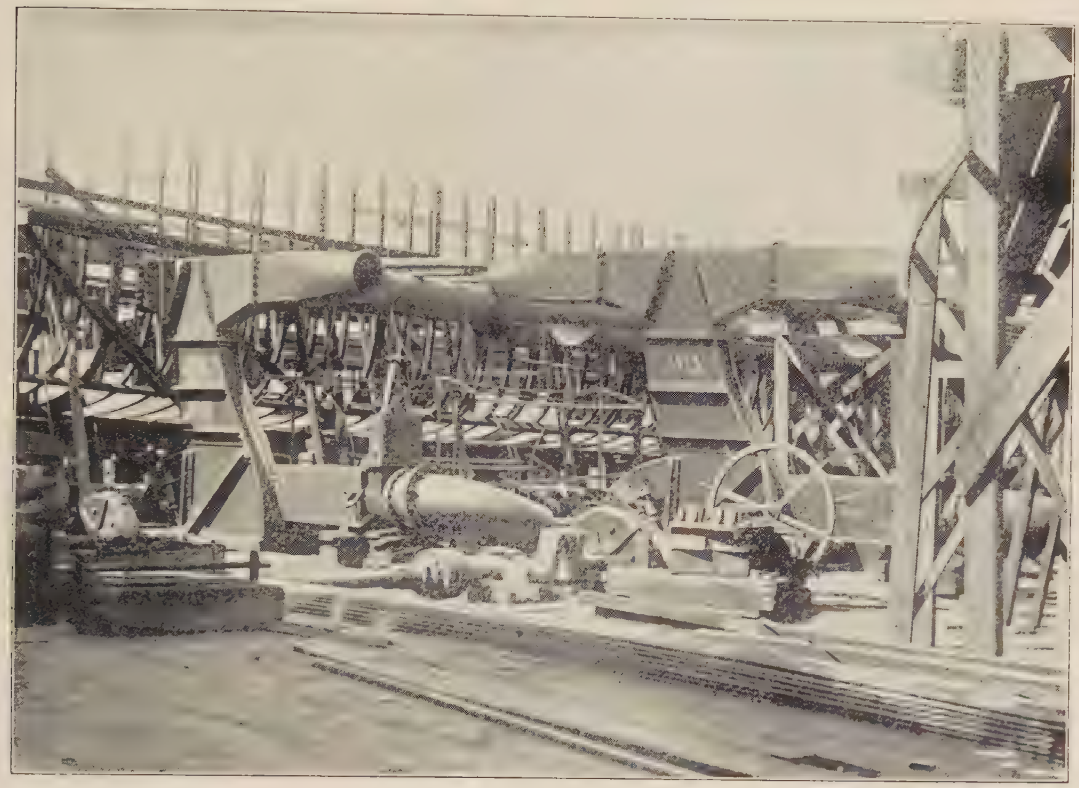


FIG. 81.

Although the above-mentioned suction dredgers were chiefly used at the Hook of Holland and Ymuiden, it was not long before they rendered excellent service in the harbours of Dunkirk, Boulogne, Calais and Ostend. They soon attracted the attention of English contractors, and thus we see an instance of the English, who introduced the dredging of sand by means of sand pumps into Holland, adopting suction dredgers invented in Holland.

In order to give an idea of the further development of these hoppers it will suffice to mention the *Rotterdam*, which was built in the year 1889 in the shipyard of the firm of I. and K. Smit, and the *Columbus*, built in 1892 in the shipyard of The Netherlands Steamship Company, Fyenoord.

The *Rotterdam* was 52 metres in length, 9 metres wide, and 3·75 metres deep. The hold had a capacity of 400 cubic metres, while the engine developed about 400 I.H.P.

Built in the Year	Name of Vessel.	Builders.	Dimensions of Vessel, length, width, depth in metres.	Capacity of Hold in m³.	Diameter and Breadth of Disk in mm.
1878	*Adam I.*	I. and K. Smit	—	No hold	2170 × 250
1878	*Adam II.*	*id.*	34·00 × 7·80 × 3·00	174	1480 × 275
1879	*Aurore I.*	*id.*	36·50 × 8·30 × 3·50	200	1650 × 225
1880	*Adam III.*	*id.*	42·00 × 8·30 × 3·25	214	1760 × 300
1881	*Maasmond V.*	L. Smit & Zn.	34·00 × 7·80 × 3·00	150	1730 × 250
1881	*Maasmond VI.*	I. and K. Smit	34·00 × 7·80 × 3·00	150	1650 × 225
1882	*Maasmond VII.*	L. Smit & Zn.	34·00 × 7·80 × 3·00	150	1730 × 250
id.	*Maasmond VIII.*	I. and K. Smit	34·00 × 7·80 × 3·00	150	1650 × 225
id.	*Maasmond IX.*	L. Smit & Zn.	34·00 × 7·80 × 3·00	150	1730 × 250
id.	*Maasmond X.*	I. and K. Smit	34·00 × 7·80 × 3·00	150	1650 × 225
id.	*Maasmond XI.*	*id.*	34·00 × 7·80 × 3·00	150	1650 × 225
id.	*Maasmond XII.*	*id.*	34·00 × 7·80 × 3·00	150	1650 × 225
id.	*Boulogne*	*id.*	42·00 × 8·30 × 3·25	244	1850 × 250
id.	*Maasmond XIV.*	*id.*	34·00 × 7·80 × 3·00	150	1650 × 225
id.	*Adam V.*	L. Smit & Zn.	42·00 × 8·30 × 3·42	300	2100 × 270
id.	*Adam VI.*	I. and K. Smit	42·00 × 8·30 × 3·25	244	1850 × 250
id.	*Aurore II.*	*id.*	38·00 × 8·60 × 3·25	290	1850 × 250
id.	*Amsterdam*	L. Smit & Zn.	42·00 × 8·30 × 3·42	300	2100 × 270
1883	*Adam VII.*	I. and K. Smit	42·00 × 8·30 × 3·25	300	1850 × 250

The boiler pressure was about 5 atmospheres, and the engine ran 120 revolutions per minute.

THE "COLUMBUS"

The *Columbus* at that time was the largest and latest dredger of the suction type that had been constructed, and the chief dimensions were as follows :—

Length between the perpendiculars	60 metres.
Breadth over the main frame	10 metres.
Depth	5 metres.
Total carrying capacity at deck level	725 cubic metres.

In practice this capacity was considerably exceeded.

The diameter of the sand pump disk was 2·10 metres, and the breadth 375 millimetres, while the diameter of the suction pipe was 680 millimetres (Fig. 83).

The engine was a compound engine with surface condenser, and developed, at 120 revolutions per minute, 500 I.H.P. The speed of the vessel when loaded was seven knots.

The vessel was equipped with two boilers with a heating surface of 100 square metres each, and a steam pressure of 6½ atmospheres.

The bunkers had a capacity of 700 hectolitres.

On the forepart of the vessel a steam-anchor winch was mounted with three chain pulleys, of which two worked the anchor chains, and the third the suction pipe.

On the stern there was a double steam winch with large drums to raise the doors by means of chains and blocks.

This vessel was fully equipped with steering bridge, steam steering gear, and all the other appurtenances demanded in a steamship.

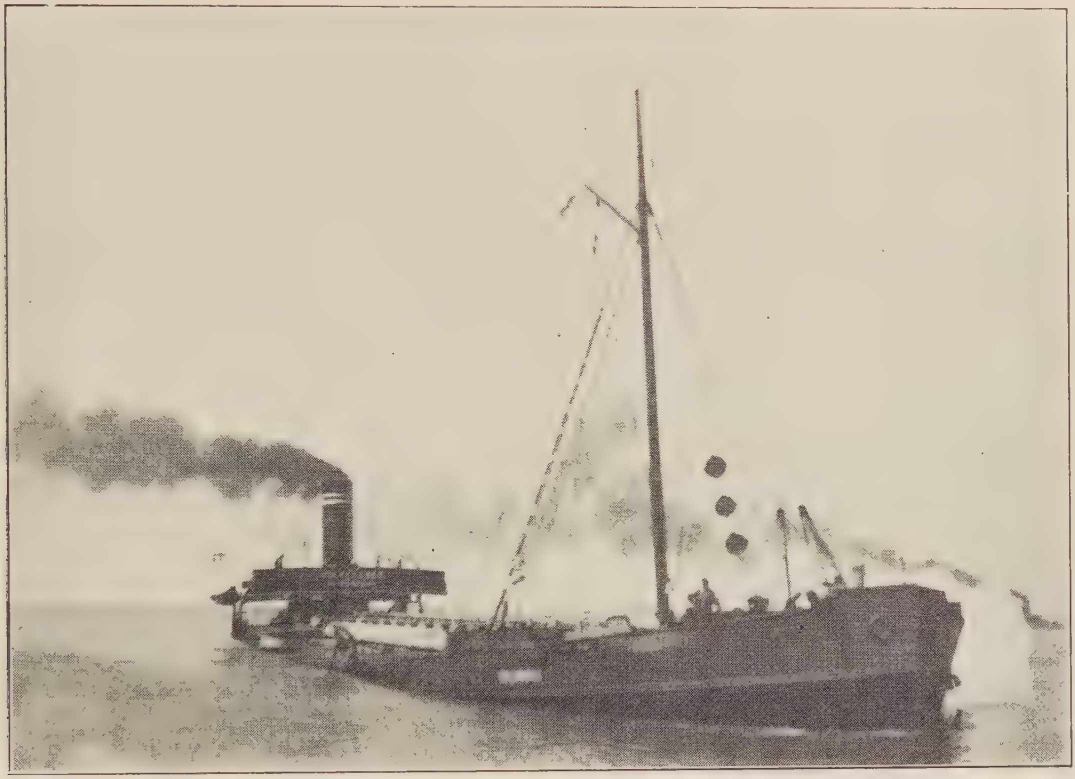


FIG. 82.

SELF-DISCHARGING SUCTION HOPPER

In the year 1895 the Dutch contractors engaged on the work for the improvement of the Scheldt, adjacent to Antwerp harbour, thought that it might be advantageous to use self-loading suction hoppers for the work which could also discharge themselves and convey the spoil to the shore.

Consequently several shipbuilding firms were invited to design a hopper answering to these requirements. From the various plans which were sent in, a project was chosen, designed by the firm of L. Smit & Zoon, for which this firm ultimately took out a patent.

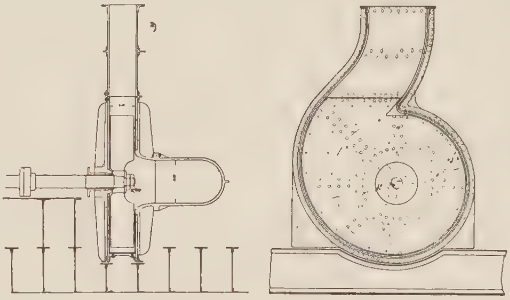


FIG. 83.

The immense importance of this invention needs no comment, since this is proved by the fact that nearly all the succeeding suction hoppers built are of the self-discharging type.

Besides the firm already mentioned, patents for similar types of hoppers were afterwards taken out by Werf Conrad, of Haarlem, and by Messrs. I. & K. Smit, of Kinderdijk.

L. SMIT & ZOON'S PATENT

The first self-discharging suction hopper, called *Schelde II.* (Fig. 84), was built in 1895 for N. van Haaren, of Nymegen. The vessel was 48 metres long, 8·60 metres wide, and 3·90 metres deep. The engine was a triple-compound one, and developed over 300 I.H.P. ; the hold had a capacity of 350 cubic metres.

In the main, the arrangement (Fig. 85) is similar to that of the ordinary self-loading hopper, except the hold, in which, above the bottom doors, a second set of doors has been placed, not unlike those of the ordinary hopper barges.

The chains of each pair of doors are attached to a yoke, which is suspended by a single chain connected with a threaded shaft. On this shaft there is a hand-wheel which serves as a nut, allowing each pair of doors to be opened or shut independently of each other. When both upper and lower doors are closed two channels are formed between them, one on the starboard, and one on the port side.

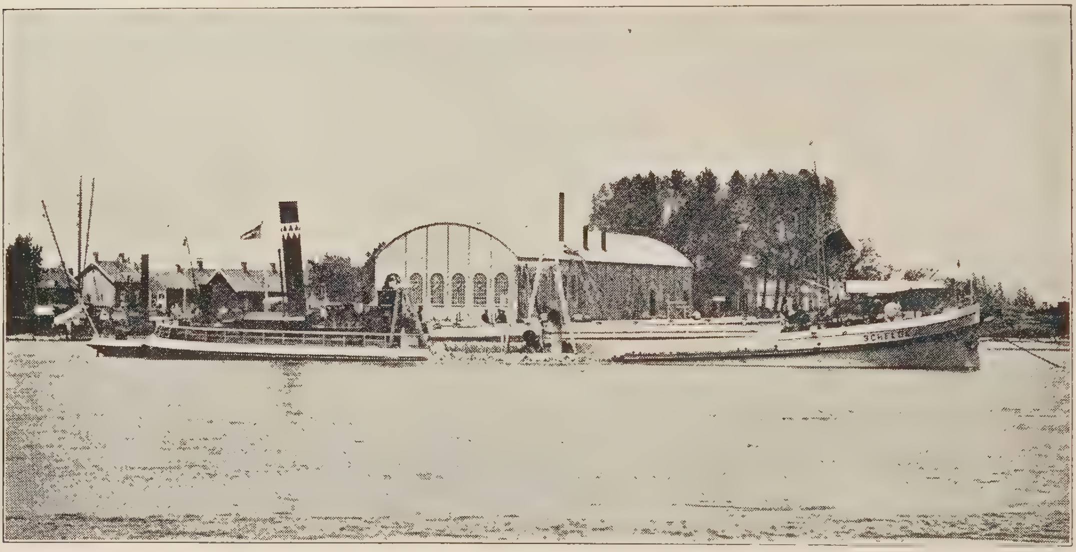


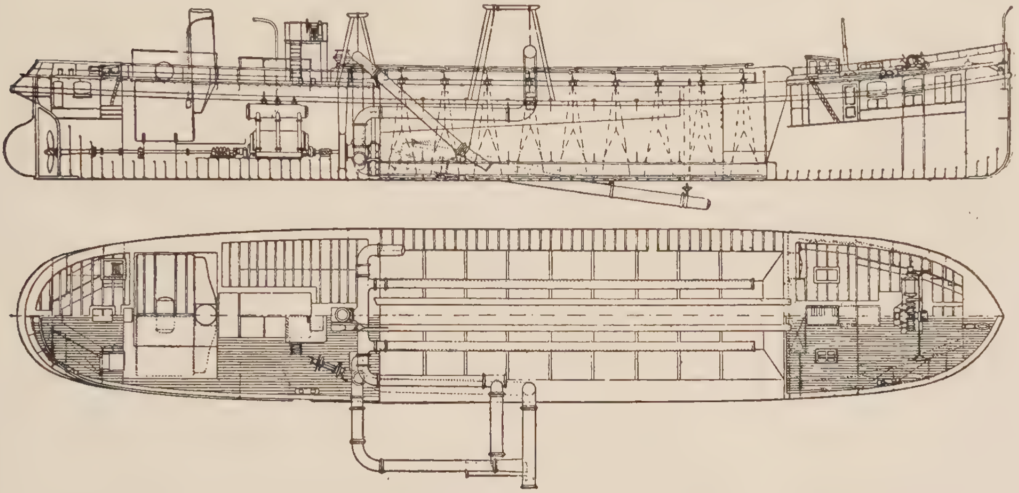
FIG. 84.

These " door channels " can be connected with the suction hole of the sand pump. There is also a valve in the suction pipe so that dredging may either take place through the pipe or through the two channels. By opening the valves the sea-water can flow freely into the channels ; the valves for effecting this are placed in the forepart of the ship against the partition of the hold.

This first self-discharging suction dredger carried its bottom suction-pipe midships, for, having to work in rivers, a suction pipe in the side of the ship stood a great chance of being damaged by the continual motion of the vessel when moored alongside the jetty of the depositing ground.

All subsequent suction hoppers on this system, however, carried the suction pipe in the side of the vessel again, as later improvements had enabled them to overcome the difficulty alluded to.

The material from the sand pump can be conveyed at will by means of suitable



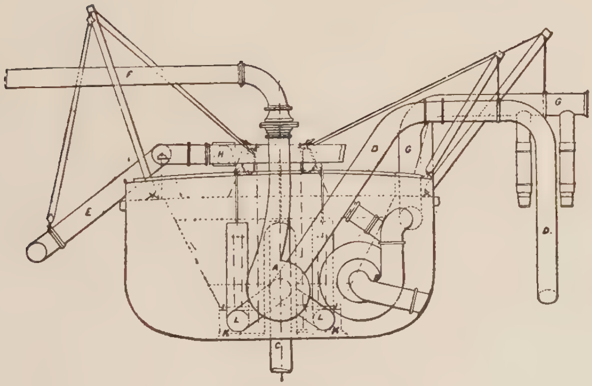


FIG. 85.

valves, either to the hold or to the shore. The former takes place in the ordinary way, while a quick connection with the shore can be obtained, as Fig. 86 shows clearly.

Immediately above the valve in the discharge pipe there is a ball-and-socket joint, the shell of which forms the beginning of the fixed discharge pipe to the shore, which is hung in a crane; this shell is lowered on to the ball as soon as the loaded hopper has been moored alongside the depositing ground.

The connection of the mantle and the ball having been effected by securing the outer mantle by means of bolts, the hopper is ready to convey its load to the shore.

The working may now be easily explained. All doors are closed, and the hold filled so that the load lies above the top doors. While going to the depositing ground the valves of the door channels are opened, and the suction pipe valve is closed.

The connection with the discharge pipe on the shore is effected, and the pump is set working, so that a strong current results in the channels between the doors. Now the top doors, beginning with those in the forepart of the ship, are opened alternately, it having been ascertained first that the sand above them is carried along by the streaming water in the channels. In this way the entire load is often forced to the depositing ground within thirty minutes.

In case it is not wanted the hopper discharges itself, the top doors are kept open so that the door channels form an extension of the hold ; if this has to last for any length of time the top doors are generally removed.

This dredger was, at the same time, so arranged that it could be used as a barge-discharging suction dredger as well as for shaping ground to accurate forms, levels and slopes (Profile dredger).

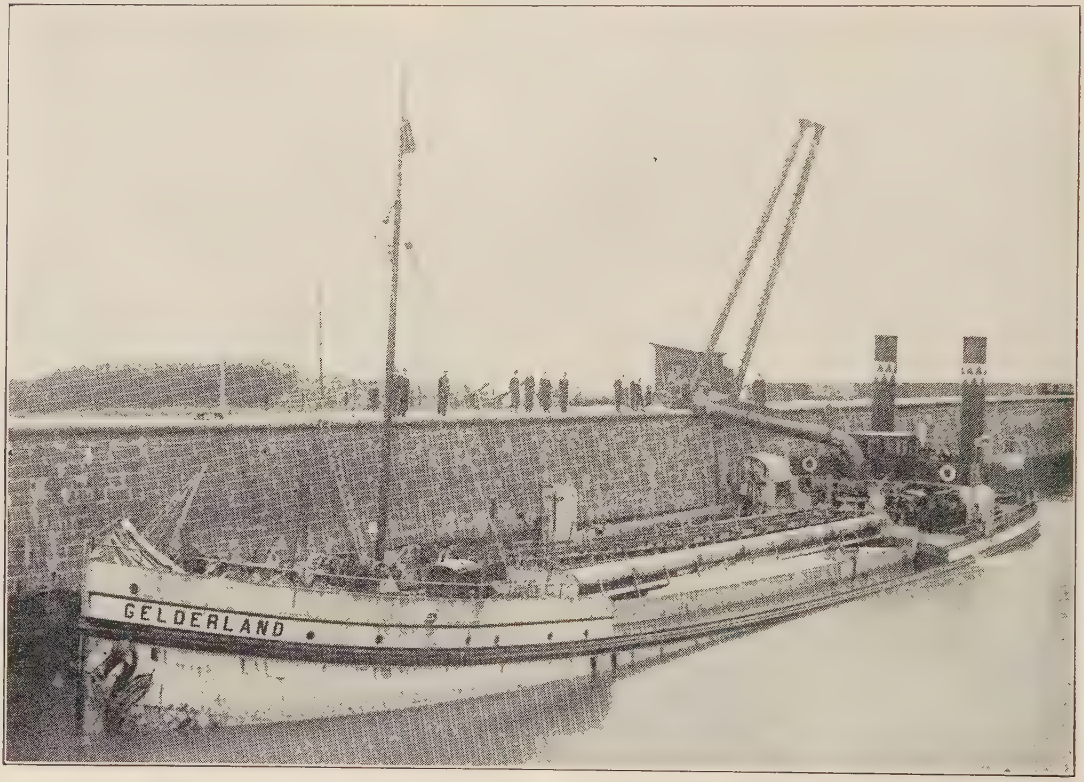


Fig. 86.

"WERF CONRAD" PATENT (Fig. 87)

In this system the bottom doors are constructed in such a way that their cross-section is a segment, and all the doors fit as closely together as possible.

When all doors are closed a channel is formed on either side owing to the segment shape, a channel which, just as with the first patent, may be connected by means of valves either with the sand pump or with the sea-water at the forepart of the vessel.

The transverse bulkheads in the hold are triangular at the bottom and are furnished with valves which connect the hold with the door channels mentioned.

By opening these doors in the way that has been described, the load of sand is likewise undermined, and the contents carried along by the water current in the channels, to the sand pump, to be further conveyed to the depositing ground.

I & K. SMIT'S PATENT

Before describing this system it will be necessary to explain the word " centre box keelson," which plays an important part in this patent.

It is a well-known fact that all sea-going ships have a keelson, or garboard-strake, this being a longitudinal strengthening line of planking extending from stem to stern. With the self-loading hopper this keelson is broken off in the hold, and in its place the strengthening beams are formed in the shape of a box, which at the same time serves as the rabbet of the lower doors.

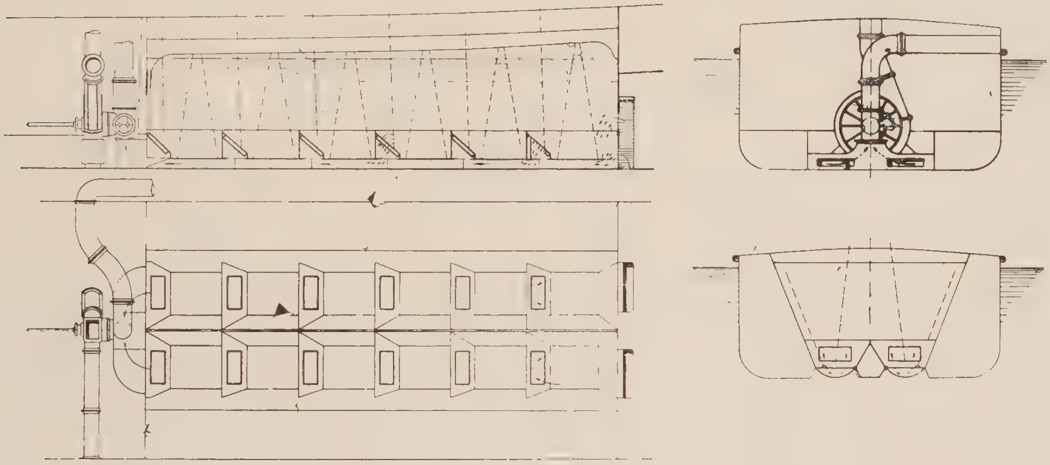


Fig. 87.

Thus the garboard-strake, or keelson, was replaced by a centre-box keelson in the hold (Fig. 88). And it is this box which, in this system, is used as the suction pipe through which the load is discharged. At one end it can be connected with the suction opening of the sand pump, and at the other with the sea-water, by suitable valves.

With each set of bottom doors there is, on both sides of the centre box keelson, a sliding shutter so that a connection is formed with the hold, allowing the load to flow into the box. The word " flow " has been used purposely, because the sand is converted into a liquid substance by saturating it with water pumped into it by a pump, specially fitted up for this purpose.

To be more explicit, suppose a tank is filled with pure sand, and that water is pumped into it until the sand is saturated and the water begins to flow over the sides of the tank ; if a cock is then opened in the bottom of the tank, the saturated sand will flow completely away.

The shutters are opened again, beginning in the forepart of the vessel, and the first set should be opened slowly because of the great pressure exercised by the liquid mass of sand, and also because the latter must be diluted by the sea-water in the box on its way to the pump.

THE MODERN HOPPER SUCTION DREDGER (*See Appendix C*)

From the foregoing we have seen how the first suction dredger has gradually developed into the self-loading and self-discharging suction hopper, and we will proceed to give a description of one of these modern applicances in order to demonstrate the various improvements that have been introduced in subsequent years.

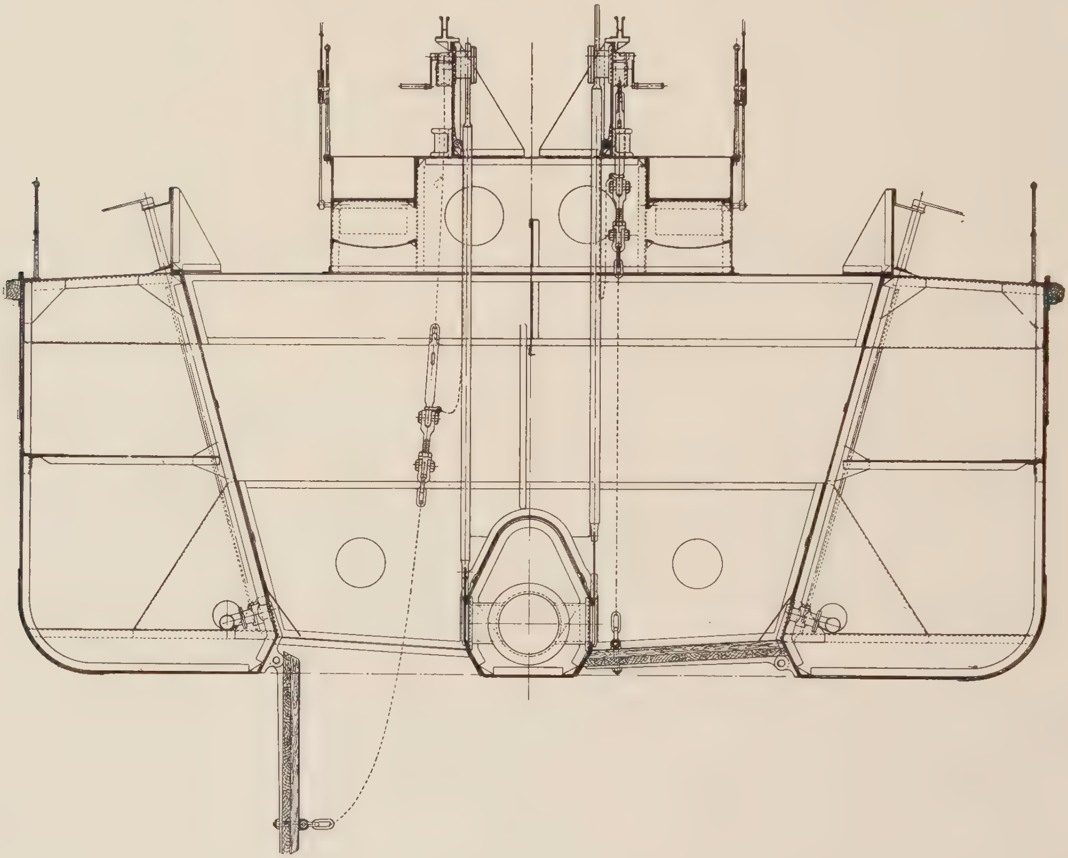


Fig. 88.

VESSEL, ENGINE AND BOILER

Of all three it may be said that they come up to the highest requirements which are demanded of any seaworthy vessel, and as a rule they are built under the special supervision of Lloyd's. the Bureau Veritas, or the Germanischer Lloyd. This is not only done to secure good work in every respect, but also to obtain the additional advantage of the lower insurance premium required, while, in case the dredger should be sold, great store is set by the fact that the documents relating to this supervision can be produced.

Besides the two watertight bulkheads at the ends of the hold, there is a third bulkhead in the forepart of the vessel to separate the accommodation of the captain, engineer and sailors from the water tank and the storeplace for the anchor chains. Aft, there are also various partitions for the accommodation of the firemen, the bunkers and the stokehold, the boiler room and the engine room.

The steam anchor-winch is exactly similar to that of a sea-going ship, and works two stockless anchors.

On the stern an ordinary steam winch is mounted for dropping a stern anchor ; it also facilitates mooring the vessel alongside the depositing ground.

There is also a tow hook, so that under special circumstances the hopper can be used as a tug.

Right across the ship is the bridge, with cabin, in which there are a steam steering gear, compass, telegraph, speaking tube, and all the further requirements needed for a sea voyage ; a ship's bell is wanting neither, and the captain is enabled thereby to give orders to the deck crew, as is customary on dredgers.

The whole dredger is eqiupped with electric lighting, and a couple of arc lamps serve to secure adequate surveillance on board and on the depositing ground.

The lifeboat and all other things belonging to a sea-going ship are all present according to the regulations.

Turning to the details which bear more directly on the vessel as a suction dredger, we shall start with the hold, as it is directly connected with the dimensions of the vessel, and, as such, has great influence on the chief parts, such as the power of the engine, the heating surface of the boilers and the diameter of the suction pipe.

THE HOLD

The capacity of the hold has gradually been increased, although the Dutch Government engineers were not always in favour of it. The *Columbus*, for example, when finished was considered too large for the upkeep of the waterway from Rotterdam to the sea, as it was thought that the pits it dug were too large, and suction dredgers with a smaller hold were preferred. In how far this view was right we shall leave undecided ; but, in spite of it, hoppers of larger capacity were built for works where these objections were not raised. Thus, for example, a suction hopper was ordered by the firm of Ackermanns & van Haaren with a hold of more than 1,200 cubic metres, called the *Gelderland*, built by Messrs. L. Smit & Zoon (Fig. 89).

This vessel is 75 metres in length, 12½ metres wide, and 5½ metres deep, and is equipped with two triple expansion engines, indicating 600 H.P. each, at 120 revolutions per minute, equalling 1,200 I.H.P. in all, with a load capacity of 1,200 cubic metres.

Both engines have their own condenser and work independently.

Steam is supplied by two boilers, with a heating surface, each of 208 square metres, at a pressure of 12 atmospheres. In the stokehold there is an auxiliary boiler of 15 square metres heating surface, worked at a pressure of 10 atmospheres, which is used

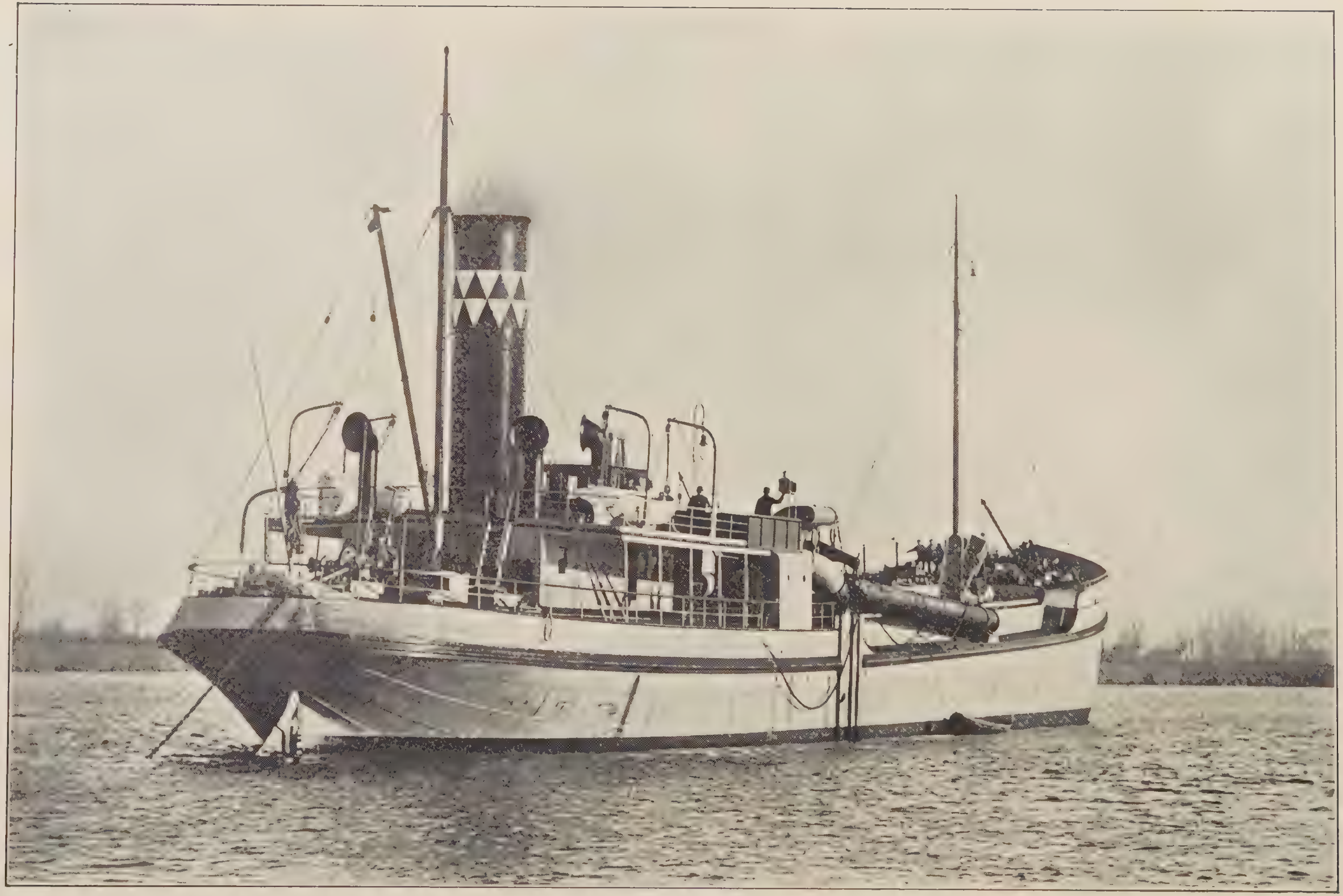


Fig. 89.

for working the winches and auxiliary machinery, and for circulating the water while the large boilers are raising steam.

When we compare the proportion of the figures represented by the I.H.P. to the capacity of the hold in cubic metres of this and other dredgers that have already been described, it will strike us that this proportion is the same in nearly every instance, so that it would seem to be a safe rule upon which all future calculations can be based. the more so as it is clear that there is a direct connection between the two. Should special demands arise with regard to the speed of the vessel, or the distance over which the spoil has to be conveyed, the power, of course, has to be proportionally increased.

Between the final bulkheads there are, by each side rabbet of the doors, open transverse partitions which at the bottom are connected with the centre box keelson, and at the top with the gangway which spans the hold from one end to the other, and forms a connection between the forepart of the vessel and the stern (Fig. 89A).

Under the centre of this gangway there is a vertical strengthening plate, which extends into the hold, and at the same time serves to give a uniformly distributed load, a thing which must be specially taken care of when the hold is nearly full, and the empty part is consequently divided over its full length into two equal parts by the strengthening plate, so that one can direct the supply of sand either to starboard or port. This is the more necessary because a suction dredger when working is always drawn down on the side where the suction pipe is found.

On each side of the gangway there are steel sockets with steel cotters, to which the bottom doors are attached ; while on the outside against the vertical sides of this passage the threaded shafts with the handwheels are found, by means of which the upper doors are opened and closed.

In the middle the hold is divided by a closed transverse bulkhead into two equal parts, and material can be led into either of these at will ; while one compartment is filling, the spoil in the other has time to settle.

The discharge pipes of the sand pumps are led over the deck to both the starboard and the port side of the hold ; over each door compartment these pipes are provided with square holes which can be closed. Under each of these holes a plate breaks the fall of the spoil in order to prevent pits from forming themselves in the load.

Instead of the discharge pipes, another method of construction is sometimes preferred, viz., under the gangway the discharge takes place in the same way on either side of the vertical strengthening plate (Fig. 88).

The upper doors are similar to those of the ordinary hopper barges which have already been described.

The bottom doors should also be made to close tightly as the very fine sand will trickle through even the smallest opening and thereby be lost. This is why doors are preferred that are shaped like a trapezium. The lower and larger door consists of a heavy plate hung on hinges. A wooden filling-piece attached to this plate serves to make it fit as tightly as possible. Each door is suspended by two or three chains attached to a short cross-beam, to which the hoisting chain is fastened ; to each cross-beam a short saftey chain is attached.

A steam winch equipped with two steel wire-rope drums works the starboard and port lower doors.

THE SAND PUMP

The shape of the pump did not undergo any great alteration. As we have already seen, the pump of the *Adam I.* was equipped with a corner-piece. Various drawings show that subsequently the form that was given to the casing of the pump, starting from the corner-piece, was that of the water-centrifugal pump, which it very closely imitated, as is shown by the sketch of the sand pump of the *Columbus.*

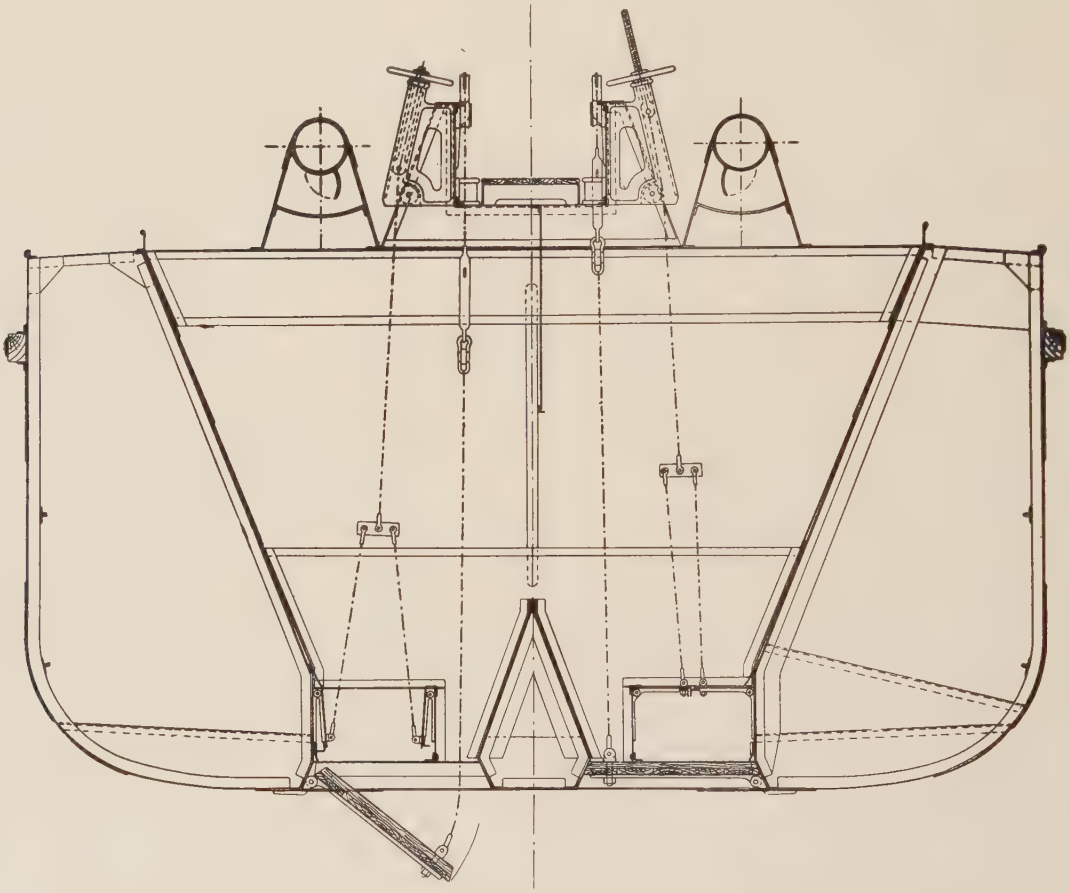


Fig. 89a.

Practice soon proved, however, that the results were not entirely satisfactory, and the idea was soon abandoned in so far that the outer circle of the disc reached to the centre of the discharge pipe. As soon as the pump had to convey the spoil over a great distance the casing capacity had to be even smaller.

The casing of the pump, which formerly was made almost exclusively of angle and plate steel, is now usually made of cast steel, leakage at the rivets being thus prevented, while the construction is cheaper. The pump is provided with easily renewable wearing plates ; the corner-piece, too, can be renewed.

The disc is an open one and has three or four blades, the number depending on the capacity of the pump. The *Gelderland* has a three-bladed disc with a diameter of 2·20 metres, and a width of 360 millimetres. The diameter of the suction pipe is 88 centimetres.

The disc is of forged steel of first-rate quality, and carries loose blades which are attached to the arms by means of bolts and nuts. Abroad, closed discs are sometimes used. These, however, cannot be so easily renewed, as the entire front cover would have to be detached for this purpose, while with the open disc only the upper half of the cover need be removed. Moreover, objects that are drawn in by the pump sometimes get stuck in the closed disc and revolve with it (Fig. 90).

It is considered to be an important improvement to place a water chamber between the bottom ring and the stuffing box-gland of the disc shaft. A duplex pump feeds this water chamber continually with water under pressure so that the drawing-in of air through the gland is prevented. This also prevents the sand penetrating the stuffing box should the engine stop unexpectedly owing to the disc getting stuck. The water chamber is provided with a safety valve and a manometer.

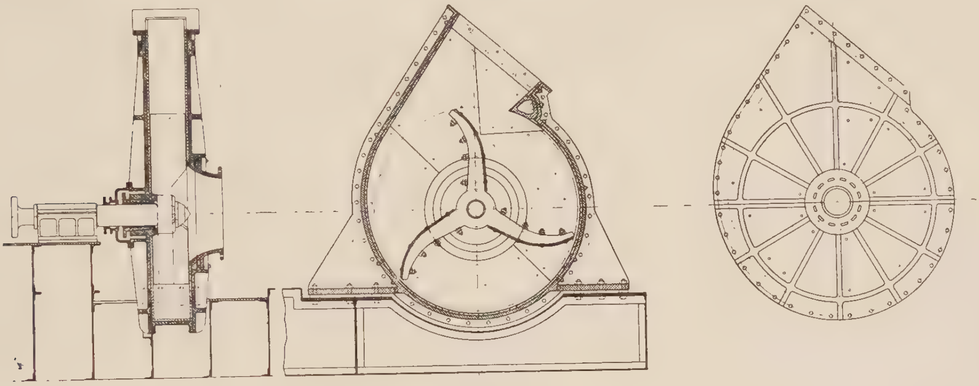


Fig. 90.

The disc shaft is made no longer than is absolutely necessary, and is provided with a steel lining from the disc to the outside of the gland. A bearing with a large bearing surface should be placed as near as possible to the sand pump, while it is advisable to have a separate thrust collar block.

The inlet, or "mouthpiece" of the pump, has a wearing rim. Immediately behind this mouthpiece there is a fairly large manhole cover which can be quickly opened and closed in order to remove objects that have been drawn in, but which cannot pass.

Immediately in front of the sand pump a crane is attached to the deck, so that it is possible to detach the front cover quickly, in order to inspect the pump or to renew the disc or the shaft.

To prevent the wear of the lining plates, manhole covers in the sides of the pump should be avoided, as each seam in itself causes wear.

In the suction pipe, as has already been said, shutters or sluice valves are found, which operate when the dredger is unloading; there is also a shutter in the bottom suction pipe near the place where it is joined to the side of the vessel. Fig. 91 shows the shutters generally used for this purpose.

COUPLING GEAR

Several methods are in use for setting either pump or propeller shaft in motion. The simplest, and by no means the worst, method, is by the removal or insertion of coupling bolts into fixed coupling flanges, which are mounted on all the shafts. Another way is to use the ordinary claw clutch. Sometimes the claws are replaced by turned steel pins.

Triangular coupling sheaves, over which a clutch can be made to slide, which makes or breaks the connection in the ordinary way, are also sometimes used (*vide* Fig. 92). In the latter case there are also three coupling bolts provided, which may come in very useful, for example, on a long sea voyage. It is clear that any system which is quick and reliable may be used.

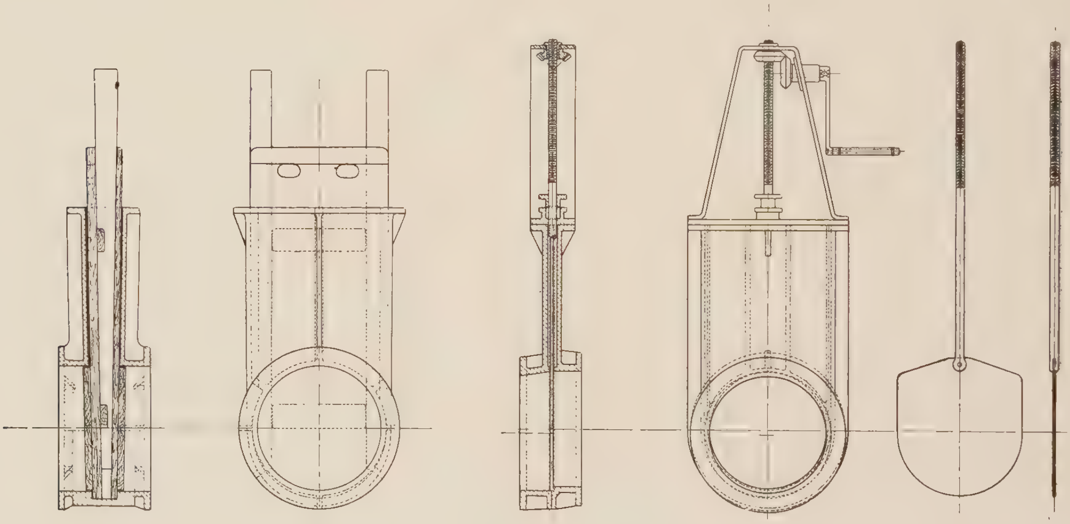


Fig. 91.

The *Gelderland* has the ordinary claw-clutch on the sand-pump shaft and an ordinary flange-coupling with bolts on the side of the propeller shaft.

On the propeller shaft there is a small disc fitted with brake in order to stop this shaft when it is uncoupled, which otherwise might be moved by the current of the river.

Large dredgers especially should be equipped with a steam-turning gear, which can be done without any great extra cost by combining it with the Stephenson link-motion, provided the " all-round " system is used.

SUCTION PIPE WITH LIFTING APPARATUS, SYSTEM L. SMIT & ZOON

An ingenious method has been devised for lifting the leather bag, and the bend piece in the minimum of time, either into the gangway or along the side of the vessel, so that a serious obstruction to the motion of the loaded vessel through the water can be removed, and there is less danger of their being damaged. An additional advantage is that the leather bag can be more easily renewed (Fig. 93).

The bend-piece and the trestle, from which the suction pipe is suspended, can move in a vertical direction along guide bars attached to the outside of the vessel. These guide bars join similar guides attached to the framing of the hoisting crane. In the top of the crane there are two steel wire-rope drums of the same size attached to the same shaft by means of which the bend piece and the suction pipe can be simultaneously raised or lowered.

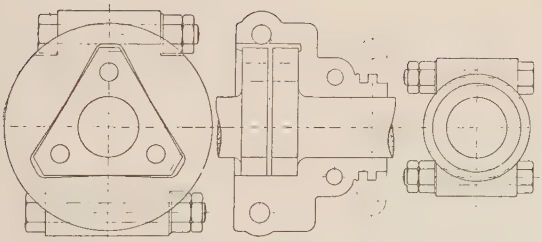


Fig. 92.

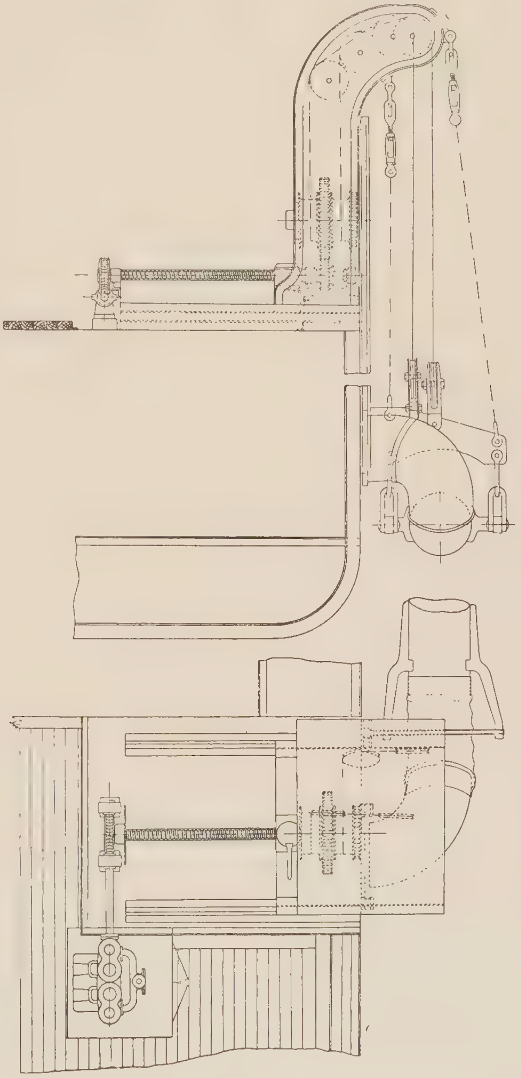


Fig. 93.

The hoisting crane is placed on slide bars so that it can be moved across the deck towards midships, far enough to bring the suction pipe entirely aboard.

The bend carries a smoothly planed and square flange with conical studs cast on at the corners, which enables it to be placed close against the hull of the vessel opposite to the suction pipe opening, where it fits a smooth flange-face riveted on the side of the hull. The four conical studs have corresponding recesses in the lower part of the guide, which enables the two surfaces to assume the correct position in relation to each other.

A vertical steam engine of two cylinders, placed on deck, serves either to work the steel wire-rope drums or to move the crane over the slide bars by means of a threaded shaft with brass nut.

The end of the suction pipe is hung from a hoisting crane which is so constructed that the two tackle blocks touch each other when raised as high as it will go. When the pipe is in this position it can be taken aboard by the hinged crane girder in which the pipe is hung, which can be made to move backwards sufficiently far to reach the centre of the gangway (Fig. 94). The crane girder is fixed in this position by means of a simple steel pin which passes right through the crane. By paying out the cable the suction pipe is lowered into a special saddle which for the same purpose is also attached to the other end near the leather bag.

"GEOPOTES," 1, 2, 3

Before dropping this subject we will take a look on board of the above-mentioned twin-screw self-loading self-discharging suction hopper (Appendix D).

These vessels have been placed in the highest class for this kind of ship in the Bureau Veritas classification (Fig. 95).

The chief dimensions are as follows :—

Length of ship from stem to stern	60 metres.
Breadth, measured over the main frame	10 metres.
Depth of the sides	5 metres.
Loading capacity to deck level	650 cubic metres.
Loading capacity to top of washboard	725 cubic metres.
Speed when loaded	8 knots (about).
Heating surface of the two boilers	250 square metres.
Two triple compound engines of 350 I.H.P. each at	175 revs. per minute.

The engines are equipped with self-acting surface condensers with a vertical air pump of the Weir monotype.

Diameter of sand-pump disc	1·75 metres.
Breadth of sand-pump disc	0·30 metres.
Diameter of the suction pipe	0·65 metres.

The discharging takes place according to the patent of the builders, for which purpose a steam pump is placed in the engine-room to dilute the cargo.

In the centre-box keelson there is a cast-steel suction pipe of 70 centimetres diameter, with mouthpieces of the same size, which discharge on either side into the hold above the centre of each door. By means of steel slide valves the supply from the hold to the pipes can be regulated at will from the bridge.

The force water from the steam pump is led through pipes to each door compartment just opposite the suction holes of the centre-box keelson. In each compartment there is a cock which can be opened from the deck.

The sand pumps can, independently of each other, pump material either from the sea or from the hold, while they can also force the stuff at will both to the shore and to the hold. They can be, moreover, coupled in series which is especially useful when the spoil has to be conveyed over a long distance.

It is an important advantage to be able to have one pump only at work on the sea bottom; for, as a rule, these suction dredgers work in the mouths of large rivers where the sand that has to be dredged is very fine, and which consequently settles very slowly. In order to make it settle more quickly it is best to make the supply no larger than is strictly necessary. It has also been proved that with fine sand the hold can be more quickly filled by one pump than by using both (Fig. 96).

Yet another advantage is that when only one engine is working the furnaces of the boilers can be cleaned, after which both engines can take the vessel, at full steam with both engines driving the propeller, to the depositing ground (Fig. 97).

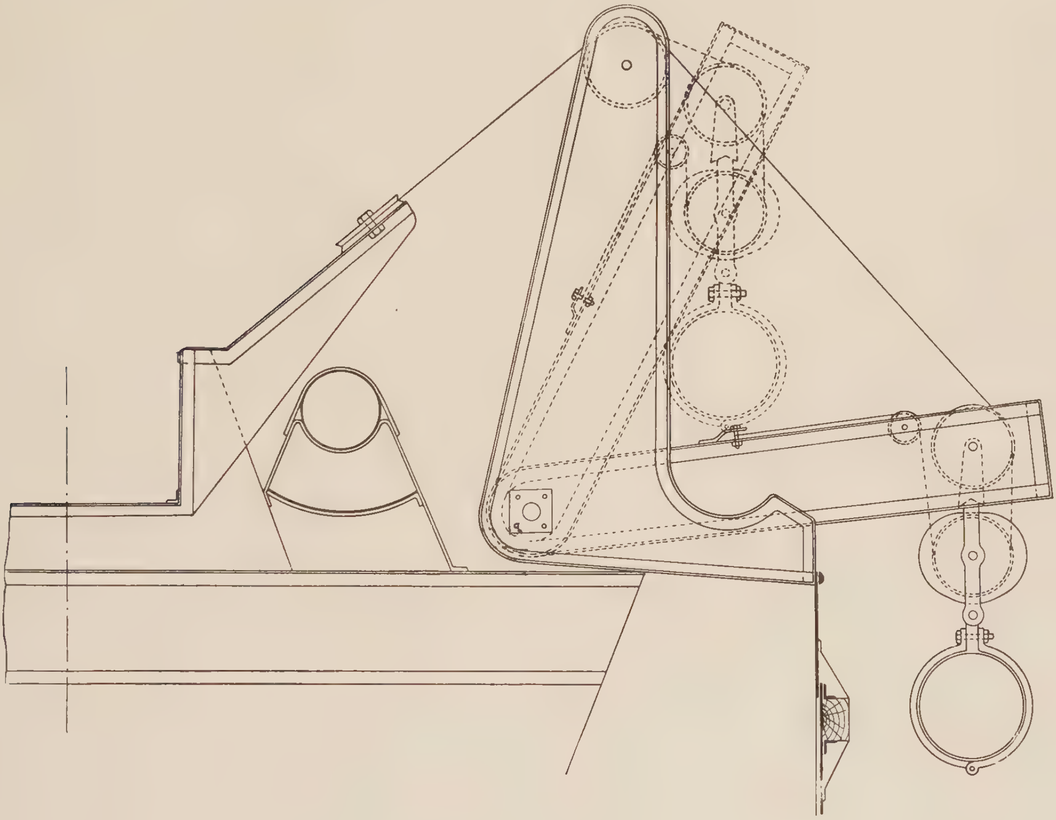


Fig. 94.

The suction dredgers are equipped with a suction pipe, of a length of 17 or 23 metres as desired; for this reason there are two bedplates, so that the hoisting crane may be placed on either of these at will. An advantage of the long suction pipe is that when drawing from a great depth it may be placed in a more favourable position with regard to the vessel than a short pipe, which otherwise would be in a nearly vertical position. It may also happen that the sand at a great depth can be more easily drawn up than that near the bottom surface, which is very often the case in places where sand has already been removed and where the finer sand has settled again (Fig. 98).

The special construction of the hoisting cranes is worth noticing. They have

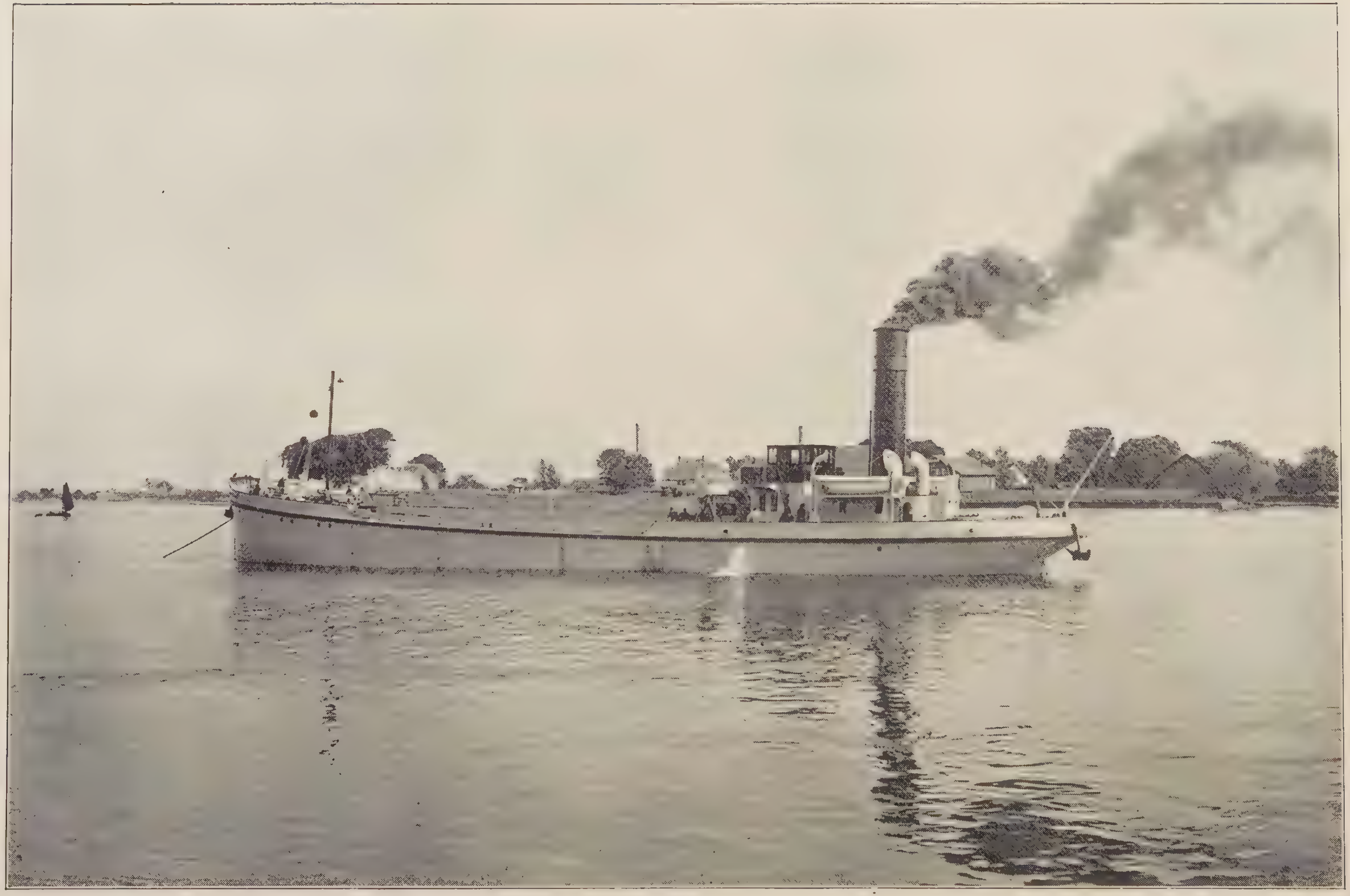


Fig. 95.

been constructed to the design of the builders. The principle is the same as that of a roll-bascule bridge ; as soon as the blocks, by which the pipe is lifted, touch each other the cranes are pulled right backwards, and a pawl and a steel pin hold them in the desired position ; by paying out the lifting wires the pipe is lowered into position in its saddle, for which a space has been set apart in the framing of the cranes (Figs. 99 and 99A). Figs. 99B and 100A are suction dredgers of English construction.

The advantage of this method is that the pipe can be run out and taken on board in the shortest possible time.

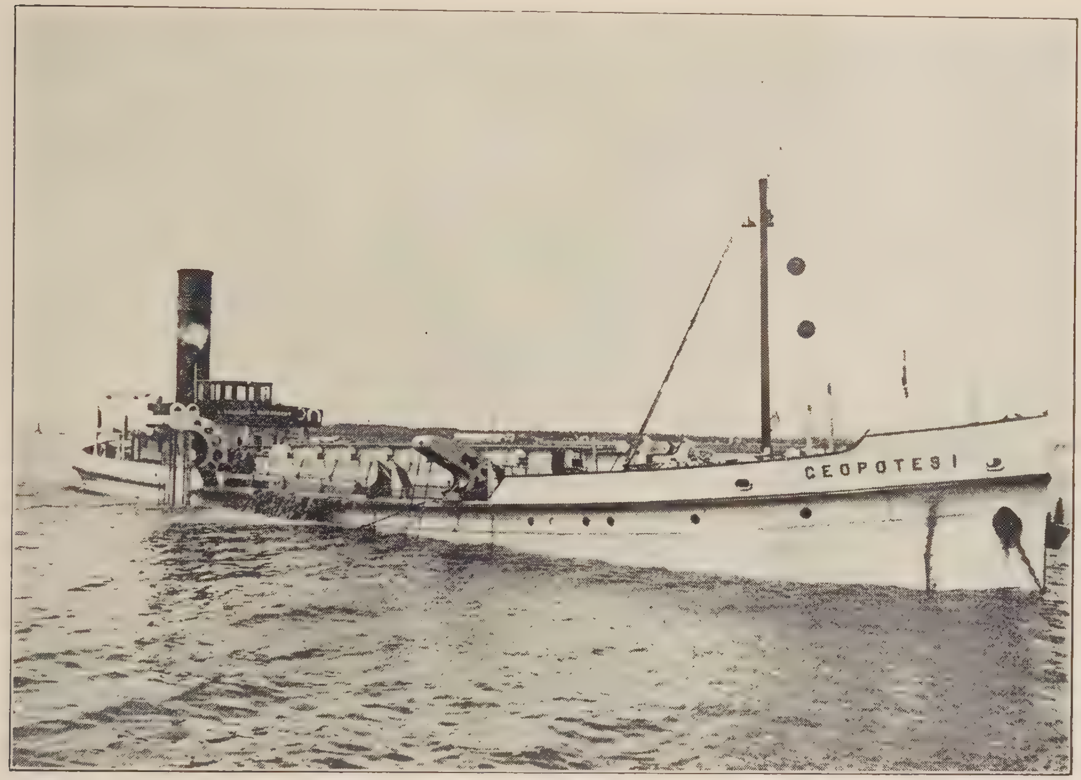


Fig. 96.

MUD-SUCTION DREDGERS

The great success achieved with the sand-suction dredgers, especially from the economical point of view, induced people to try if other kinds of soil could be raised by means of pumps.

In the year 1900 a patent for a mud-suction dredger was granted to Herr Otto Frühling, of Brunswick. The result was that Holland's attention was drawn to these appliances although they had never been used there, as opportunities for working with these machines are lacking. In fact it was difficult even to find suitable ground in that country where a simple trial could be made with the mud-suction dredgers built in Holland for this purpose for foreign countries.

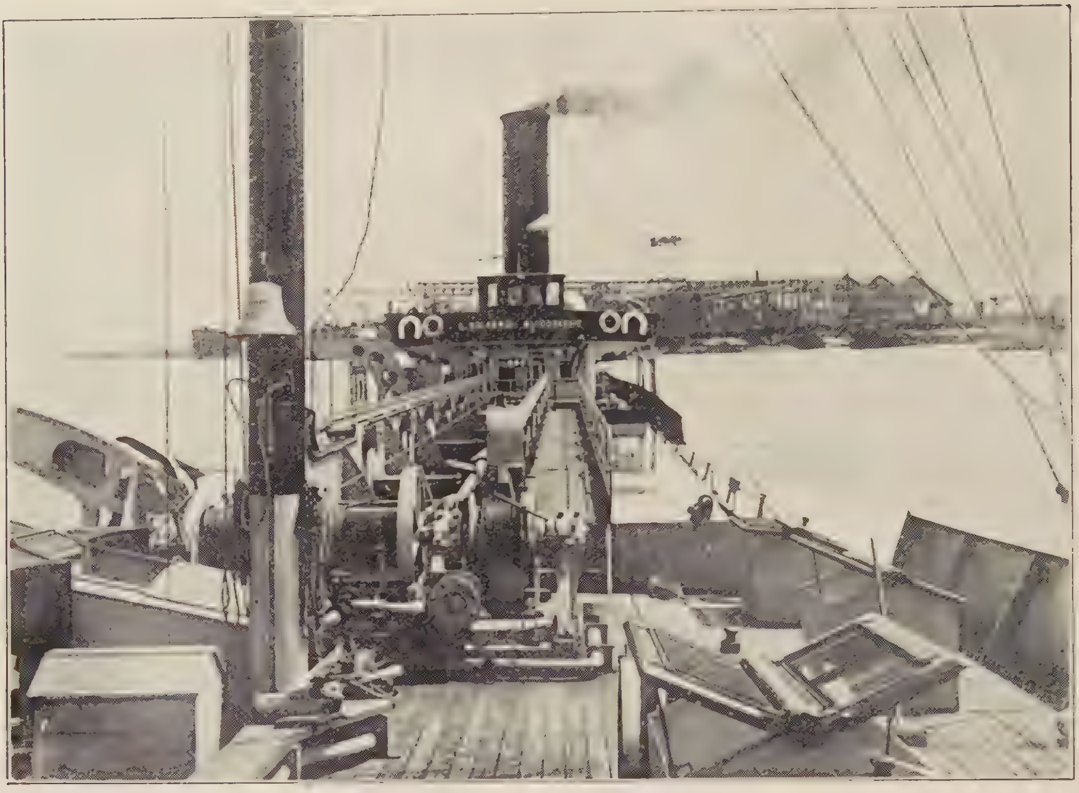


FIG. 97.

FIG. 98.

The term "mud-suction dredger" accurately expresses what is meant. Just as the sand is carried along by the current in the rivers so also are the mud particles which mix with the water, as can be clearly seen by the colour when the current is strong. In Holland people see with pleasure the muddy water of the river floods as they flow in the haughs in the spring; it leaves a layer of silt behind, which fertilises these lands.

These very light particles of mud can only settle in those places where there is little or no current; hence the silting up of harbours, into which rivers disembogue.

For the greater part these mud particles find their way to the mouth of the river. If the latter is comparatively narrow like the "Nieuwe Waterweg" from Rotterdam to the North Sea, they are dispersed in the wide expanse of the sea; if, however, the mouth is very wide, like the Elbe, for example, these mud particles find an opportunity to settle in the mouth and cause a gradual silting up, which may become very considerable, as is the case near Brunsbuttel, at the entrance to the canal, North Sea to Baltic Sea.

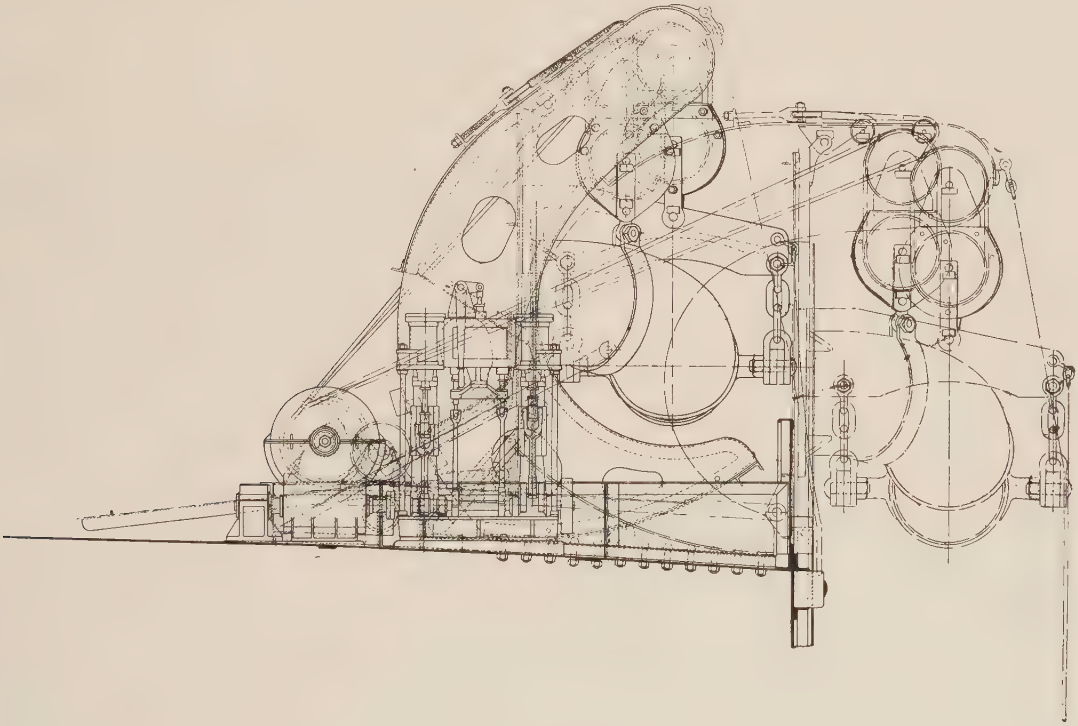


FIG. 99.

FRÜHLING SYSTEM

It was there that Herr Frühling used his mud-suction dredger very successfully (Fig. 100).

For this purpose he built a hopper-suction dredger with an open well in the stern, in which the suction pipe was placed in such a way that it was trailed along when the vessel moved. To the end of this pipe a suction-head had been attached, which, owing to its particular shape, scooped up the silt over a broad stretch. In front the suction head carried a series of grate bars to prevent large pieces of stone or wood from entering the pipe. In the suction head a shaft with blades served to dilute the scooped-up spoil with water, after which the spoil was drawn in by the pump and conveyed to the hold. It was soon found that the silt could be raised quite well without adding much water and without making much use of the blade movement in the suction head.

On each side of the well a propeller was worked by a steam engine. In front of each propeller engine there was an engine for driving a mud pump, and both pumps worked in combination on the suction head. In most cases both engines could be coupled together, which enabled the ship to attain a greater speed when the load had to be conveyed over a considerable distance.

When both engines were working the pumps the propeller engines trailed the suction head through the mud that had to be raised.

It is obvious that this method can only be used successfully where the spoil is of a very greasy nature, and which can be raised with only a slight admixture of water, and which, at the same time, causes so little resistance that the vessel can retain sufficient speed to be manageable. As soon as the soil becomes too tough, or contains too much sand, the results will be considerably less favourable. The silt which gave the best results has a specific gravity of about 1·33.

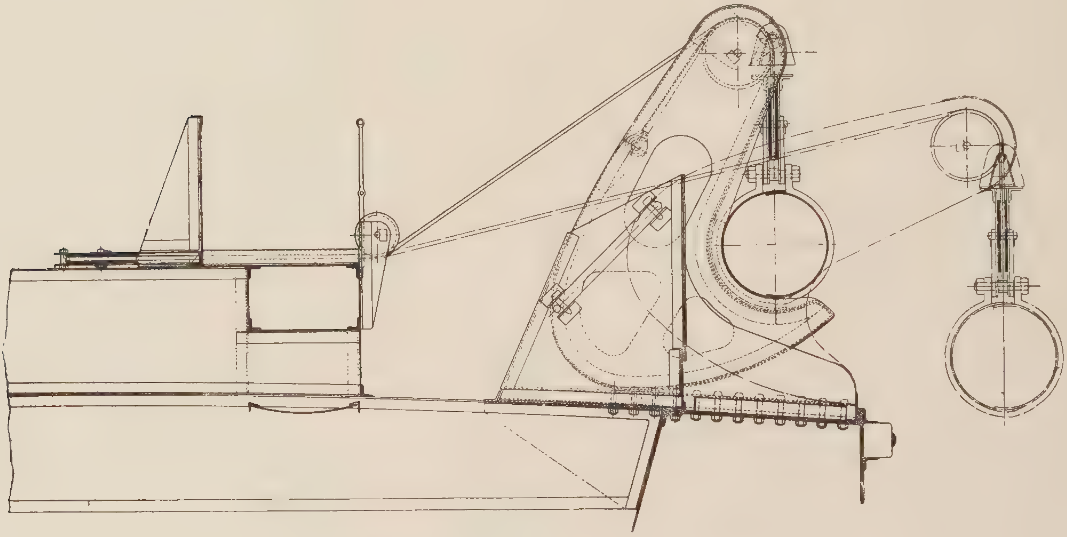


Fig. 99a.

The mouth of the La Plata River in the Argentine is subject to much silting up, and it is not to be wondered at, therefore, that the Argentine Government watched the favourable results of suction-mud dredging with great interest. In order to ascertain whether the La Plata silt could be raised by suction, an ordinary hopper-suction dredger of 500 cubic metres capacity was tried there, while a tug towed the hopper along.

The results obtained were remarkable, as may be clearly seen from the accompanying photograph (Fig. 101). The silt soon filled the hold in the form of a thick, sticky

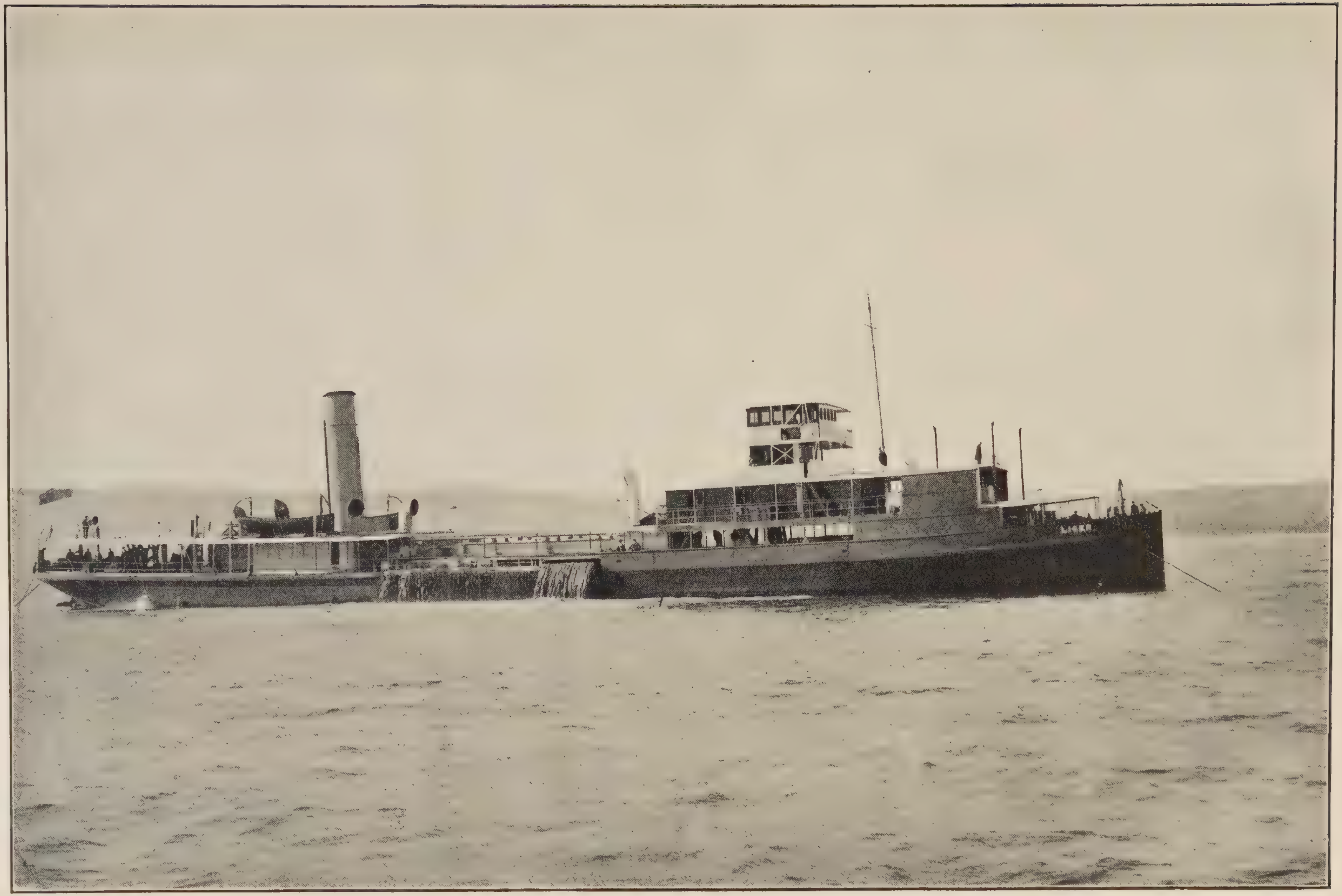


FIG. 99B.

substance. This experiment clearly proved that greasy silt may be easily raised by suction even when the suction pipe projects towards the bow.

WERF CONRAD SYSTEM

Once it had been ascertained that this silt could be drawn up, it was not long before the above-mentioned Government ordered two mud-suction dredgers, of which one was ordered from N. V. Werf Conrad, at Haarlem, while the other was ordered in England (Fig. 100B).

The chief dimensions of this vessel were as follows :—

Length	80 metres.
Breadth	14·50 metres.
Depth	6·60 metres.

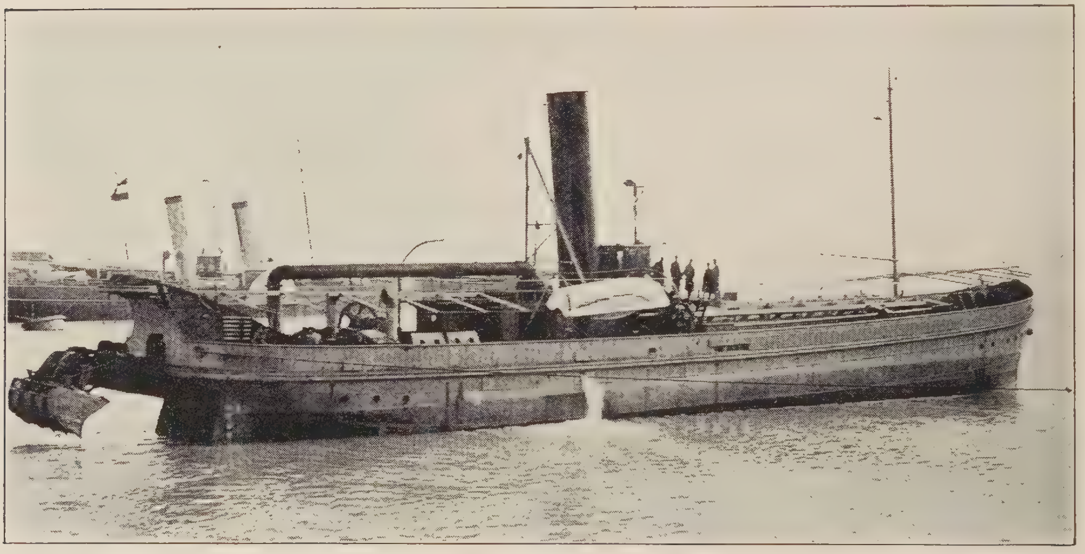


Fig. 100.

The capacity of the hold was 1,500 cubic metres, while an output of 3,600 cubic metres per hour was registered.

The speed when loaded was nine miles, or 16,668 metres per hour.

This mud-suction dredger had two suction pipes projecting towards the bow, one of which was attached to the starboard side, and one to the port side in the ordinary way as with a hopper-suction dredger.

In order to convey the silt more easily through the pipe water was pumped in at the suction opening, and also at regular distances into the pipe to lubricate the inner side of the suction pipe by means of water.

This suction dredger, too, had four engines of 500 I.H.P. each, two of which worked the propellers and two the mud pumps. Each set of two engines could be coupled together.

When sufficient experiments had been made with this suction dredger the same

Government ordered a similar one from the same yard, but with only one protruding suction pipe fitted, which was placed amidships in the well (Fig. 102).

The back of the well carried guide bars, between which the suction pipe could be lowered so that it corresponded with the suction opening (C). These guide bars also rendered good service when the suction pipe came across some wreck or other undesirable obstruction, being so constructed that they received the shock and protected the pipe from being damaged.

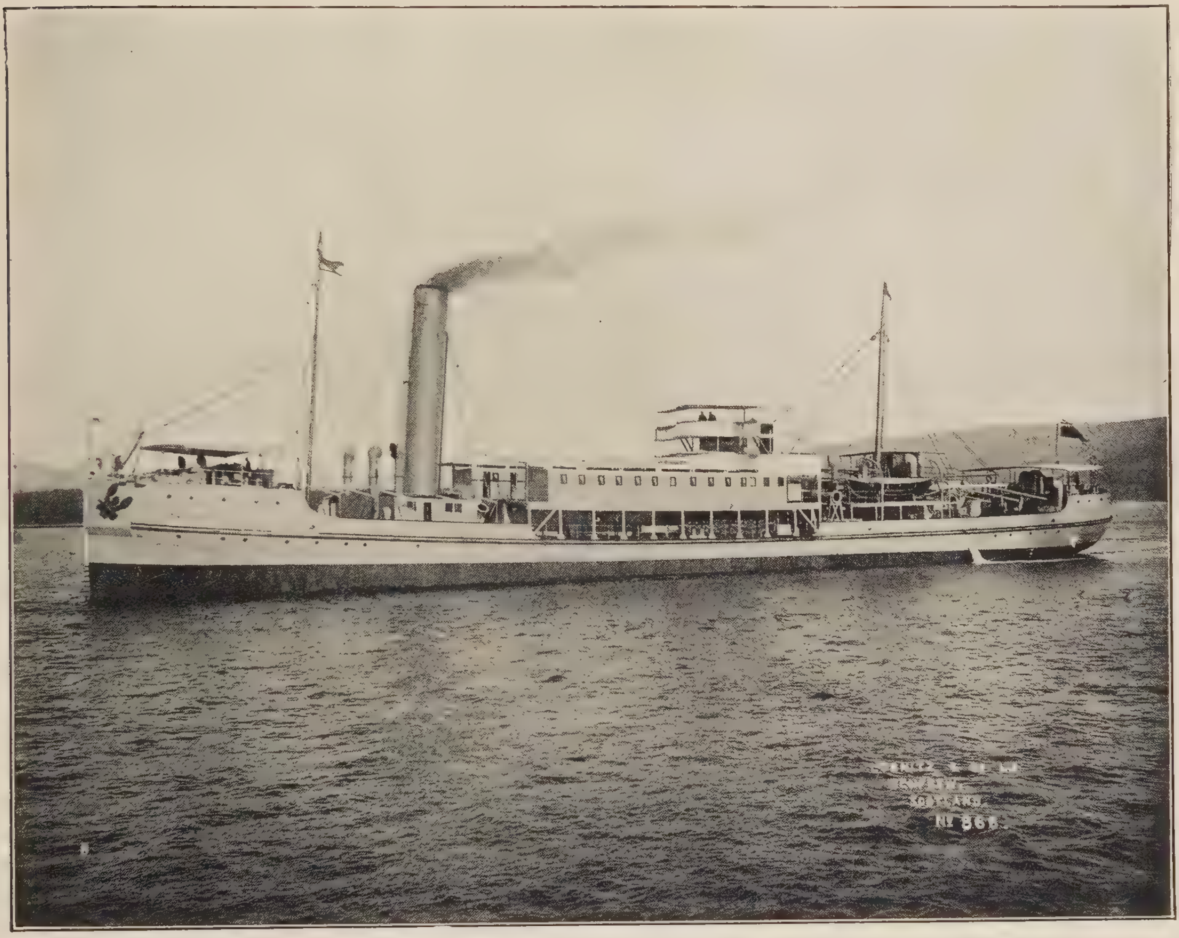


Fig. 100a.

The suction pipe can move telescopically between the wings Z from T to S, and carries at its bottom end a mouthpiece which can turn round the pin B. The result is that in cases of abnormal strain at the end K the connecting bolts of the flanges break.

The pipe is hung by the point S, and is also furnished with a towing rope MR which, when the dredger is working, is kept tightly stretched by the hydraulic hoist H, behind which a wire grip F is placed. The hoist is furnished with a safety valve V, which

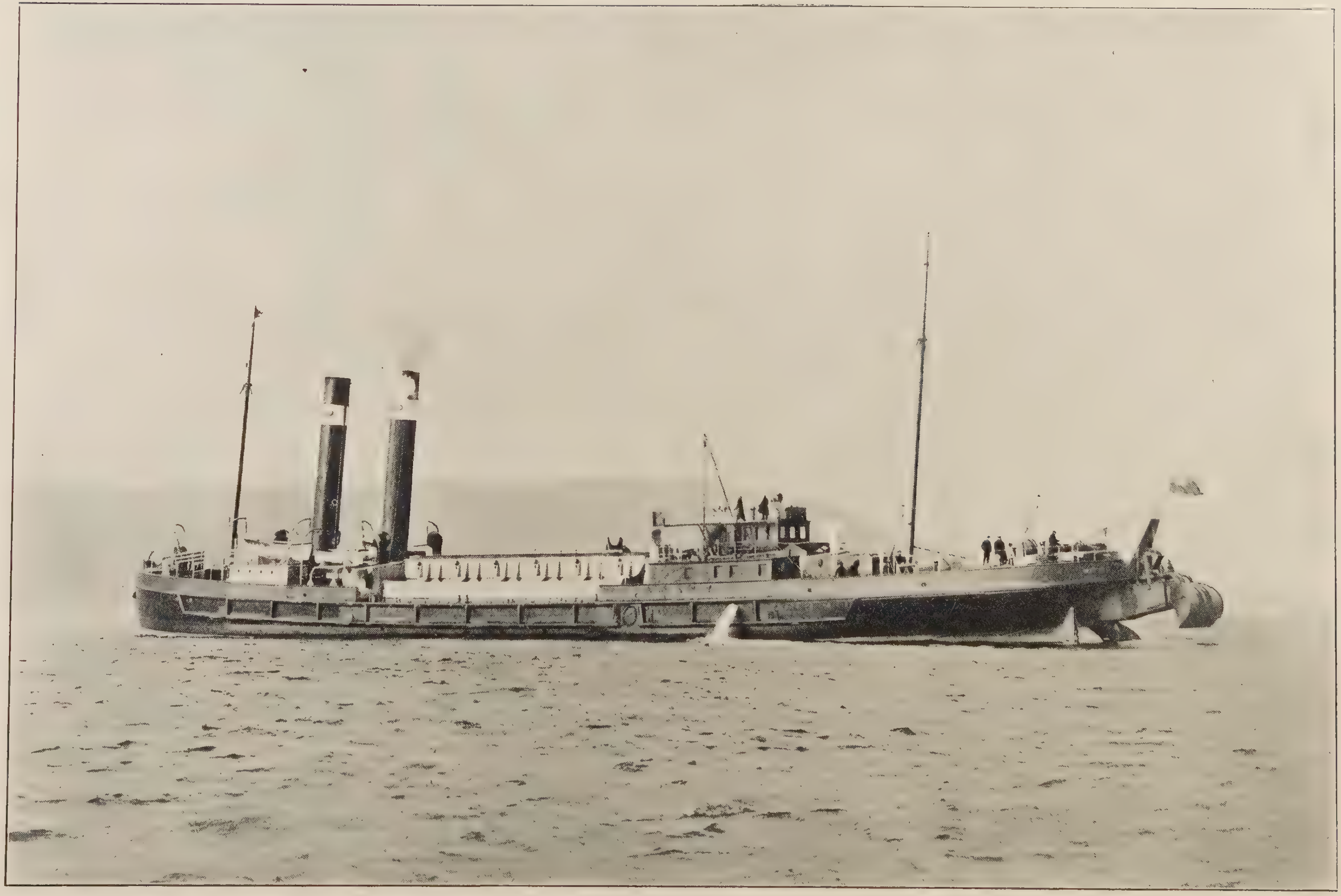


FIG. 100B.

opens automatically as soon as the tension of the towing cable exceeds the limit fixed, and permits the cable to be paid out.

At the top end the wings of the pipe are connected with springs, which allow them about 1·20 metres play, and, should the arms be moved up for any reason, the springs afterwards restore the wings to their original position.

To the wings a nose-piece *t* has been attached, which disconnects the pawl from the guide bar *g* as soon as the suction pipe has come to the end of its telescopic movement.

Let us see now what happens when an abnormal strain is exercised on the extreme end K.

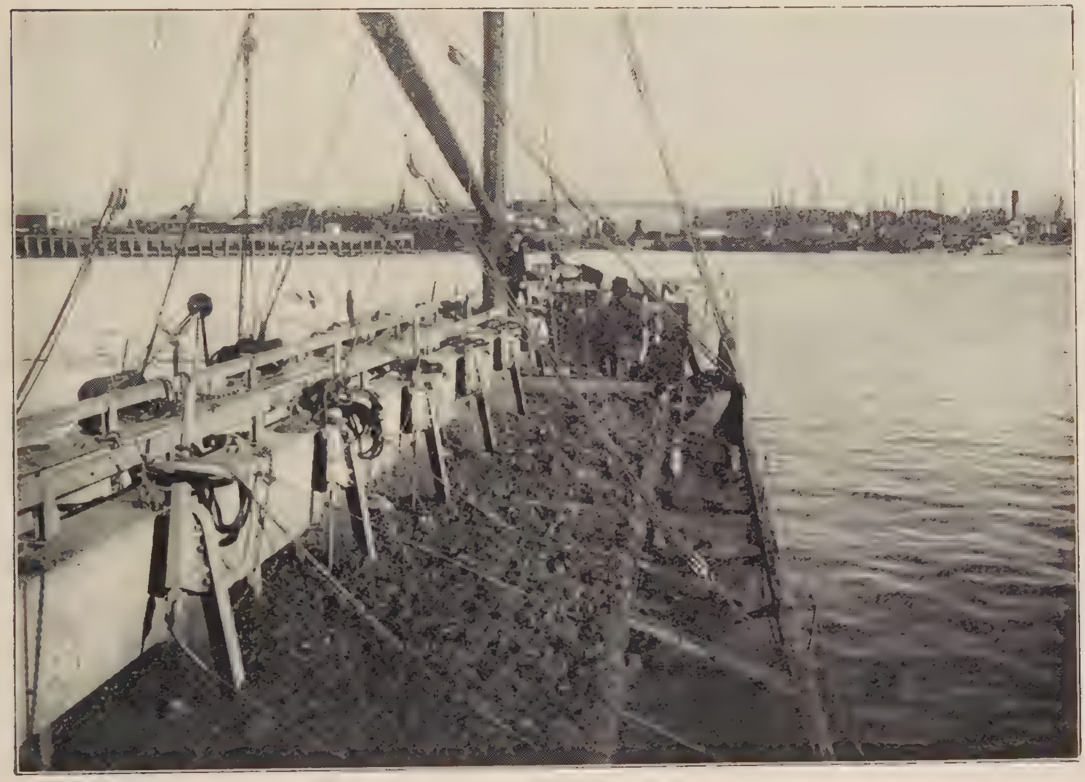


Fig. 101.

The telescopic suction pipe is pushed in, the towing rope MR is automatically paid out, and the wire *r* is stretched out. The nose-piece *t* will then lift the pawl G from the guide, and the suction pipe will successively assume the positions marked by the letters C_1, C_2, C_3, C_4. The bendpiece of the suction pipe between the guide bars carries a counterweight CP. The hold is marked by the letter N.

The two main requirements of these vessels remained, viz., the prevention of damage and the facility with which they could be managed when working under all conditions of wind and stream. These were probably the reasons why subsequent vessels were again equipped with a trailing suction pipe.

For the Dutch East Indies two mud dredgers were afterwards built, viz., the *Java* and the *Sumatra*, both to the order of the Government ; the former was built by Werf Gusto, at Schiedam, the latter by I. & K. Smit's shipyards, at Kinderdijk, both having trailing suction pipes.

The suction pipe of the first " Frühling " mud dredger was placed so far backward that the suction head, when hoisted, extended far behind the ship ; on the *Java* the pipe had already been considerably advanced, so that, in the same position, the head was well within board. The suction head of the suction pipe may be compared to the tow hook of a tug. It is generally recognised that the best position for this hook is a little behind the centre of the vessel because then the tug is manageable in all directions when towing.

The nearer the suction head, when working, approaches this position, the easier the vessel can be managed. It was this fact which probably led the builders of the *Sumatra* to place the trailing suction pipe so far forward that the head, when working was but little behind the centre of the vessel.

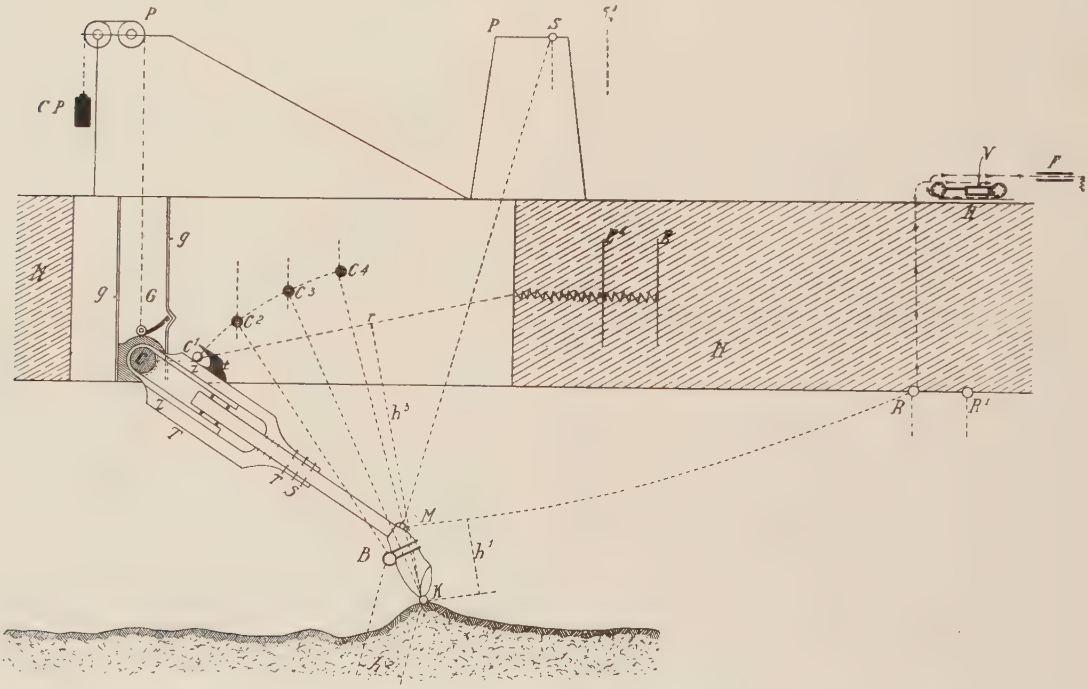


FIG. 102.

The experiments made with this suction dredger were not only very successful, but have also proved that when the work is in operation the vessel can be easily managed without a tug, even when working athwart the stream.

The *Sumatra* was used to improve the entrance to the harbour of Belawan (Deli). She was built during the Great War, and reached her destination under her own power.

" SUMATRA "

A detailed description of this mud-section dredger by Naval Engineer F. Smit, M.Inst. M.E., appeared in *De Ingenieur*, the weekly organ of the Dutch Royal Institute of Engineers, for March 31st, 1917, and may be summarised as follows :

The *Sumatra* (Appendix E.) is a twin-screw steamer, seaworthy in every respect, and was able to make the voyage to the Indies under her own power (Fig. 103).

She is equipped with a central suction pipe, placed in a suction well, which is again placed in the centre of the hold.

Unlike other mud dredgers with trailing suction head, the contact of the suction pipe with the sea bottom is almost under the centre of the vessel in order to make the vessel easily manageable. Experiments have proved that this construction has great advantages over one by which the suction pipe is placed more towards the stern.

By placing the hold well in the centre of the vessel the ship can be easily trimmed when being loaded, and there is, moreover, greater freedom as regards the arrangement of the stoke and engine-rooms.

The vessel, with the engines and general equipment, was built according to the rules of the Bureau Veritas under special supervision, and has been classed in the highest class ✠ ⦶ 3/3 D.I.I.

The chief dimensions are :

Length between the perpendiculars	85 metres.
Greatest breadth	13·50 metres.
Moulded depth	6·50 metres.
Draught with a load of 2,320 tons	5 metres.
Dredging depth	from 6 to 14 metres.
Capacity of hold	1,300 cub. metres.

Seven watertight bulkheads divide the vessel into the following eight watertight compartments.

1. The forepeak, used also as a water-ballast tank, above which there is a storeroom with chain well.
2. Front storeroom, above which is accommodation for the officers.
3. Engine-room for the mud pumps.
4. Holds with well for the suction pipe.
5. Boiler-room with coal bunkers athwartship.
6. Engine-room for the propeller engines.
7. Back storeroom, above which is the accommodation for the native crew.
8. Fresh-water tank, above which there is a chain box.

Each airtight compartment alongside the hold is again subdivided by three partitions into four watertight divisions, while the holds on either side of the suction-pipe well have three partitions each, which rise to a height of 1 metre below the upper edge of the boards of the holds.

The thwartships bunkers have a joint capacity of more than 235 tons, while the hindmost compartments alongside the holds are used as reserve bunkers for about 75 tons of coals ; in the holds themselves another 600 tons may be stored for the voyage out.

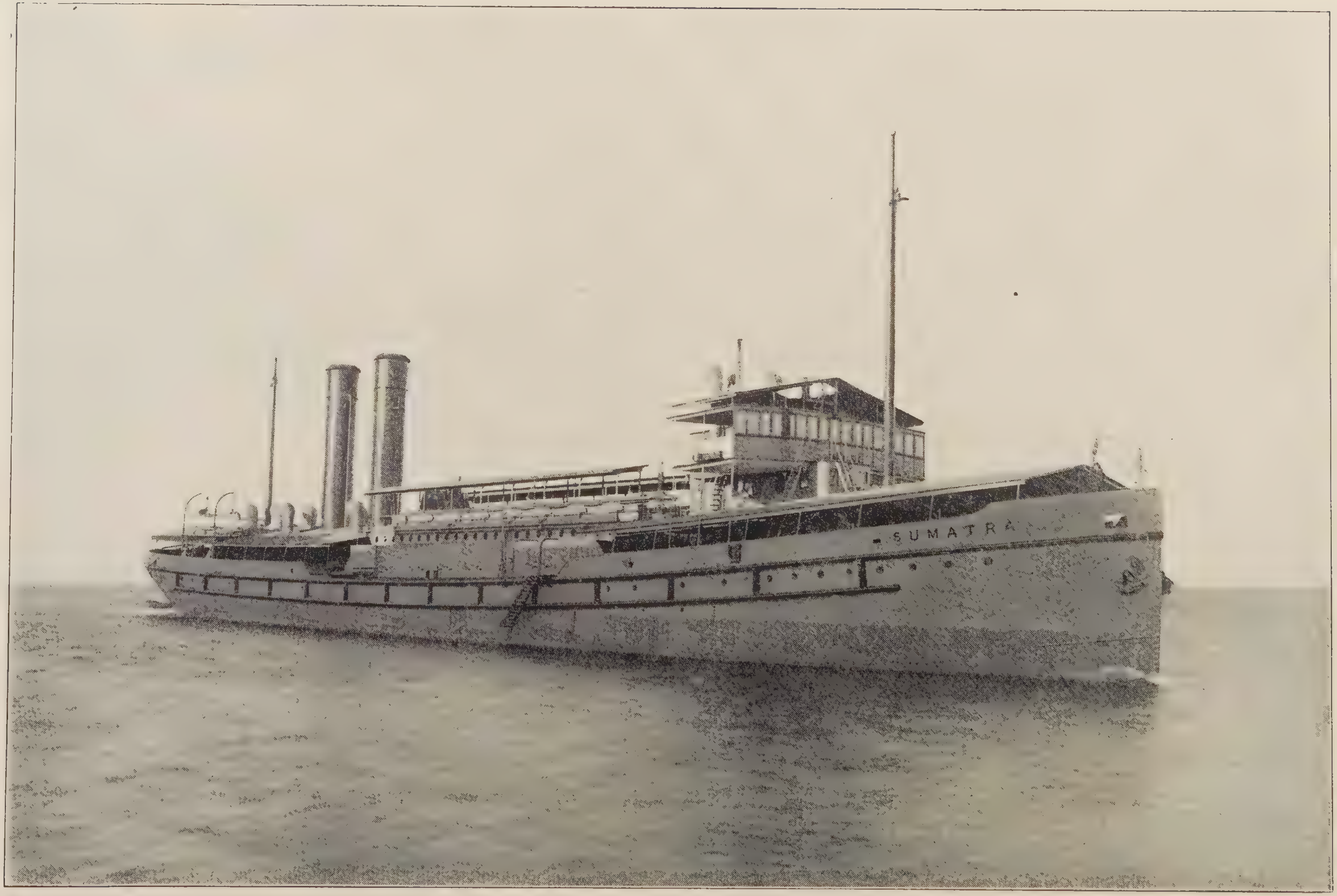


FIG. 103.

The forepart of the vessel is spanned over its full width by a navigating bridge, which also enables the master to have a good view of the discharging of the spoil into the holds and overboard, as well as of the excess of water flowing off.

The bridge is closed in front by windows that can be lowered on hinges, and at the sides and at the back with canvas.

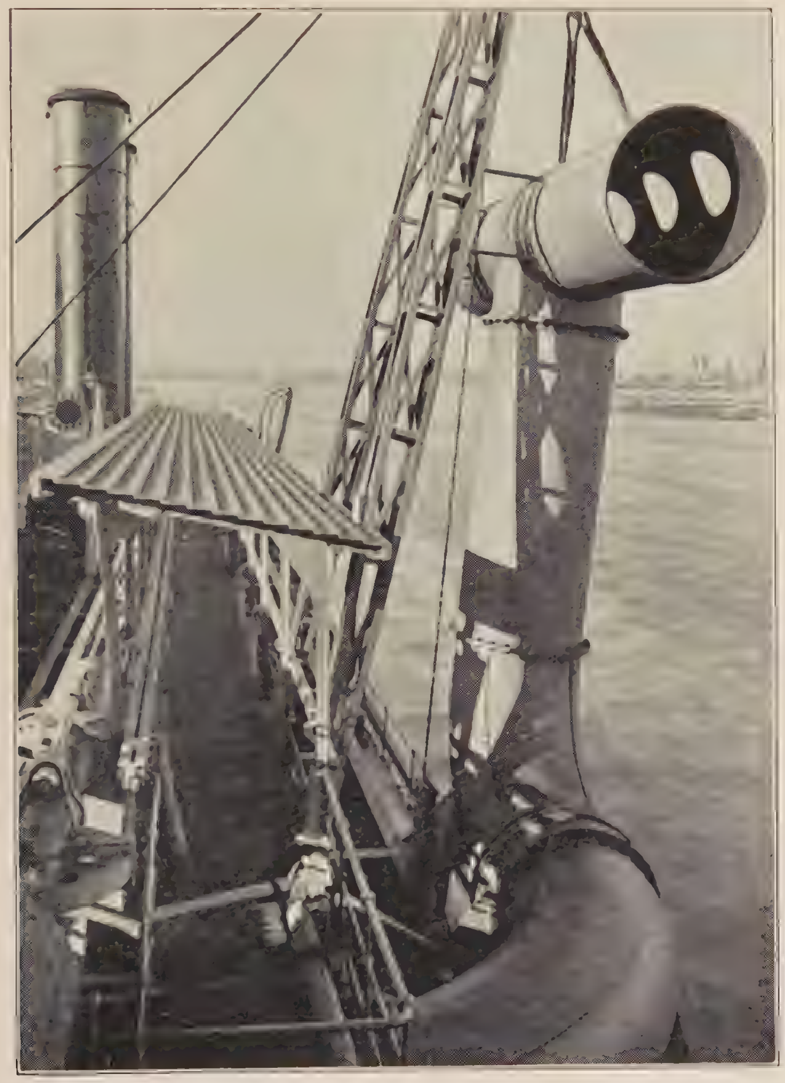


Fig. 104.

On the bridge are a telemotor for operating the feed regulator of the steam steering-gear (which is placed in the deck cabin behind the engine room), the compass, the chart table, etc., besides speaking tubes and telegraphs; in short, everything wanted for navigation, including the manometers and vacuum meters of the suction and discharge pipes as well as those of the mud pumps, and a manometer for the main steam piping.

An appliance for lowering the suction pipe to the depth required, and the handles for the regulation of the shutters which convey the spoil either into the hold or overboard, are also placed on the bridge.

The action of the *Sumatra* is as follows : the suction head having been adjusted to the required depth, both pump and propeller engines are set going and the mud is drawn up while the vessel moves along.

As, however, the dredged material contains at the beginning a large percentage of water, the spoil is not immediately discharged into the holds, but conveyed through a T-tube to outboard (for the T-tube, *vide* Fig. 104), till the mixture contains sufficient clay (Fig. 105), which can be controlled from the bridge. The slides in the pump pipes above the hods are opened then by means of the handles on the bridge, whilst the slide which leads to outboard is closed.

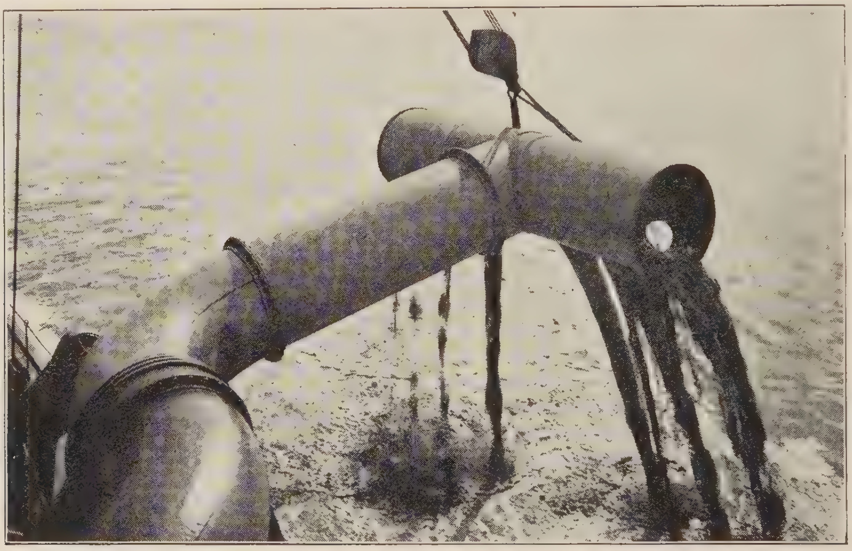


Fig. 105.

The dredged material is now discharged into the holds and can be distributed at will by means of the slides in the pipes, which are worked from the gangways above the holds.

The spoil in the holds can either be discharged into the sea by means of the bottom doors or be conveyed to the shore through the suction pipes on either side of the suction-pipe well, by means of the centrifugal suction pumps.

The slides of the suction pipes in the holds are also worked from the gangways.

In order to facilitate the discharge, water under a maximum pressure of 3 atmospheres is pumped into the holds by a high-pressure centrifugal pump driven by a compound steam engine.

The spoil is thus liquefied, and can flow into the suction pipes by opening the slides.

By admitting the seawater at the mouths of the pipes beforehand, a strong current is caused to flow in these suction pipes by the centrifugal suction pumps.

As the spoil has sometimes to be conveyed over a great distance, the pumps, which normally are coupled in parallel for dredging and discharging into the holds, may also be coupled in series.

For this purpose, just as for shutting off the other suction pipes, there are slides of special construction.

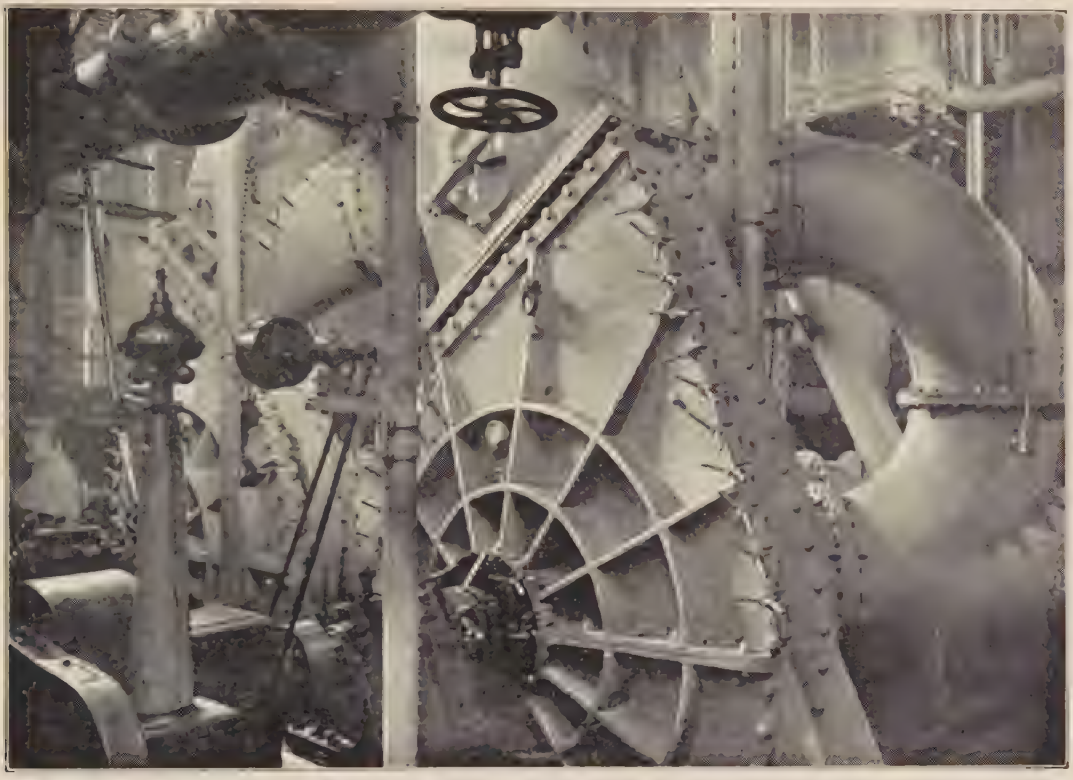


Fig. 106.

The centrifugal suction pumps mounted in the foremost engine-room are driven by triple-expansion engines of 400 I.H.P. each (Figs. 106, 107).

The pump chambers are made entirely of cast steel, and constructed in such a way that the disc and shaft can easily be taken out, so that in order to inspect the pump on the inside it is not necessary to detach the suction and force pipes first.

The pump chambers are entirely lined with easily renewable wearing plates of hard steel.

By special request the space between the circumference of the disc blades and the inner side of the pump chamber was made very large to prevent, as much as possible, the gripping of the pumps.

The central suction pipe inside the well is made of plate-steel, and placed within a plate-steel ladder which fits exactly into the well.

The suction pipe carries a suction head (Fig. 108). This head has a double casing so that the water from the high-pressure centrifugal pump can be pumped into the space between the two.

Through small holes punched in the inner casing the water streams into the suction head, thus reducing the resistance exercised by the dredged material against the inner sides of the pipe.

At the lower edge of the suction opening this water under pressure is moreover forced through slits, in order to detach the material from the bottom of the dredging ground.

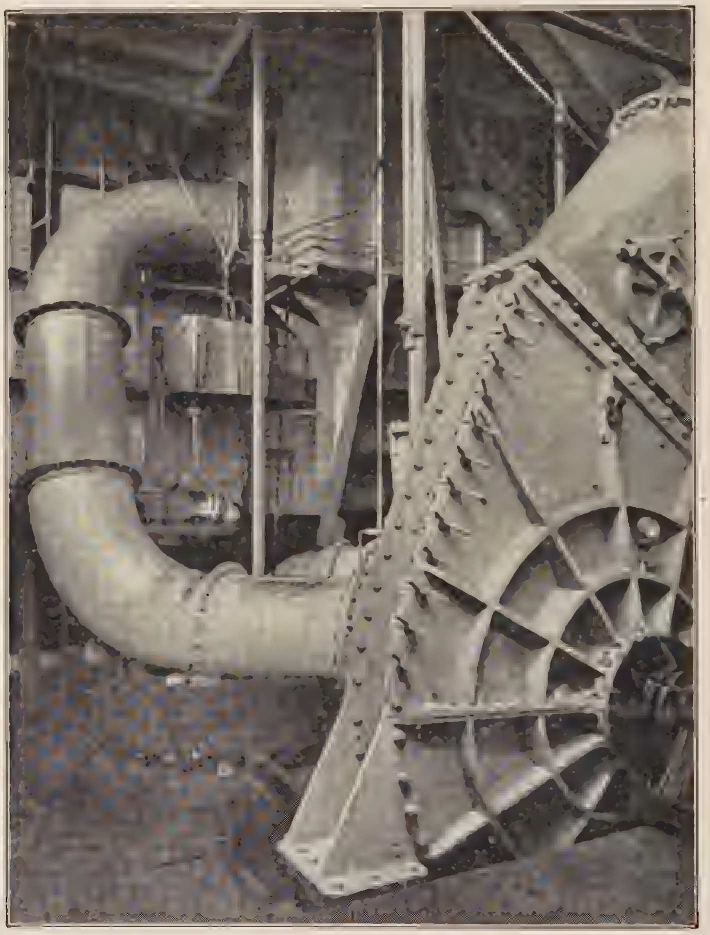


Fig. 107.

The suction head is so constructed that it opens on hinges when an abnormal resistance is met with, when the suction pipe is trailing. For this purpose there are two notches turned in the connecting bolts, and when these break the tilted suction head trails over the bottom.

When the suction head is tilted an automatic signal communicates the fact to the people on the bridge.

There are also appliances to pump the water from the high-pressure centrifugal pump into the suction pipe in order to wet the inner side of this pipe and diminish the resistance of the spoil.

At its upper end the suction tube ends in a cast-steel T-piece and moves there in cast-steel packing glands, which are attached to the sides of the well. The high-pressure water pipe, with which the suction pipe is provided, is connected with the high-pressure water pipe in the vessel by means of a bronze telescopic pipe.

The depth of the suction inlet is indicated by a dial indicator coupled to the hoisting gear and visible from the bridge (Fig. 109); correction is needed because of the varying draught of the vessel, which is indicated by a float gauge with scale divisions.

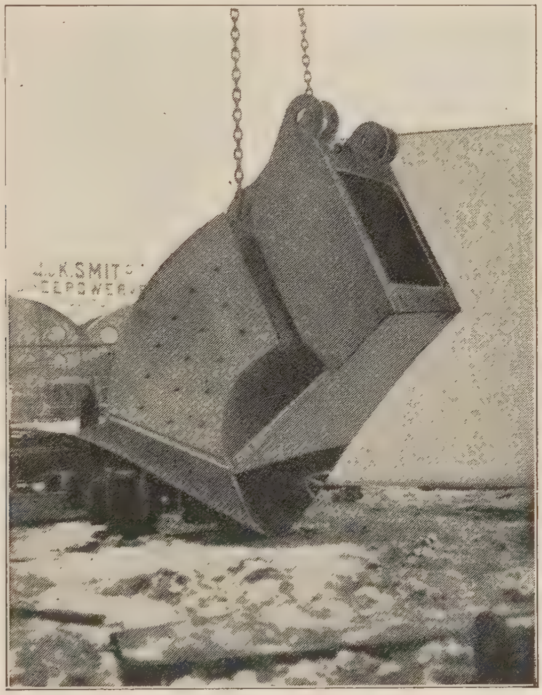


FIG. 108.

The doors of the hold are closed by means of chains and bars worked by hydraulic cylinders, and the chains for closing the doors are tightened and fixed by cotters (Fig. 110).

The high-pressure water of these hydraulic cylinders is supplied by an automatic duplex steam pump at a pressure of 60 atmospheres, which can be raised to 90 atmospheres if required.

Besides the high-pressure water for these hydraulic plungers the above-mentioned pump also supplies high-pressure water for thirty-two hydraulic cylinders which open and close the cast-steel slide valves of the two suction pipes in the holds, and of the discharge pipes above the latter ; likewise for the three cylinders on the slides which convey the dredged material either to the holds or overboard (Fig. 111), and, lastly, for the hydraulic cylinder that works the feed regulator of the suction pipe hoisting gear.

In all there are, consequently, thirty-eight hydraulic cylinders with feed regulators.

Owing to the extensive hydraulic plant the number of hands required for working the dredger has been reduced to a minimum, and, as the regulators of the hydraulic cylinders of the principal shutters are found on the bridge, all these can be managed from this central point by the dredger master, so that much time is saved, which greatly influences the output of the dredger.

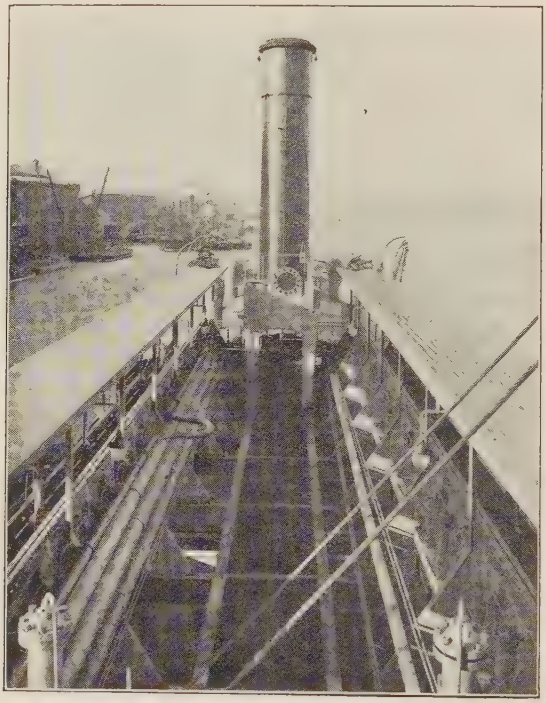


Fig. 109.

The automatic duplex steam pump, which has to work at greatly varying pressure owing to the opening and closing of the shutters, is equipped with a patented " cushion gear " to prevent troublesome and dangerous " slepping " when working at a low pressure.

A hydraulic hand pump enables the doors to be shut and the slides to be worked when there is no steam.

The engines of the dredgers are placed in two separate engine-rooms.

In the front engine-room is found the engine for working the pumps, these pumps themselves, with the piping, the high-pressure centrifugal pump with its engine, and all the auxiliary machinery belonging to the pump plant ; while in the back room are found the propeller engines with their auxiliary machinery and the electric lighting plant.

The plant in the front engine-room consists of :

Two triple-expansion engines without link motion, each of them able to develop more than 400 I.H.P., running at about 200 revolutions per minute, for working the dredging pumps.

A compound steam engine without link motion, able to develop more than 170 I.H.P., at about 270 revolutions per minute, coupled direct to the high-pressure centrifugal water pump with a three-bladed fan.

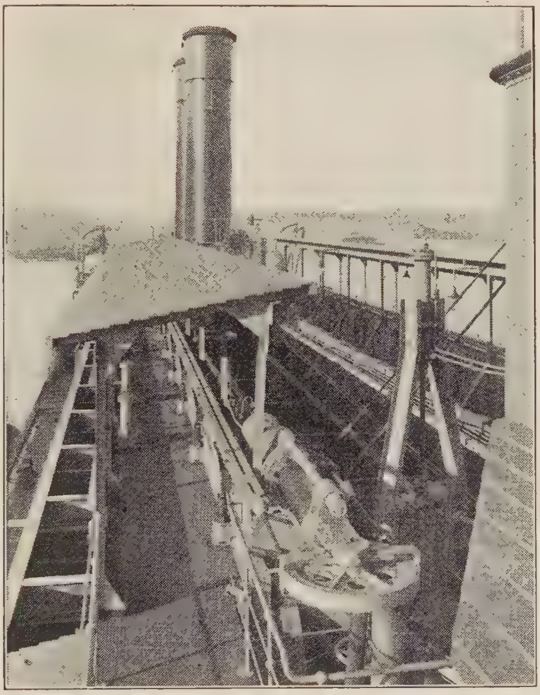


Fig. 110.

A centrifugal pump with vertical steam engine for draining a separate compartment round the dredging pumps into which the water, polluted by the spoil, flows on opening the pumps.

The hydraulic duplex steam pump described above.

A condenser of the " Fyenoord " type, with a steam-driven air pump of Weir's monotype.

A centrifugal steam-circulating pump.

A duplex bilge pump.

Two large duplex pumps for forcing the water into the glands of the dredging pumps.

In the back engine-room the plant consists of :

Two triple-expansion engines with Stephenson link motion and mechanical reversing gear.

Each of these engines can develop more than 700 I.H.P., at about 125 revolutions per minute, and drive a four-bladed screw.

There are further :

A steam-driven dynamo of 110 volts and 90 amperes for lighting the whole ship, inclusive of the signal lamps, and ventilating the cabins, etc., by means of electric fans.

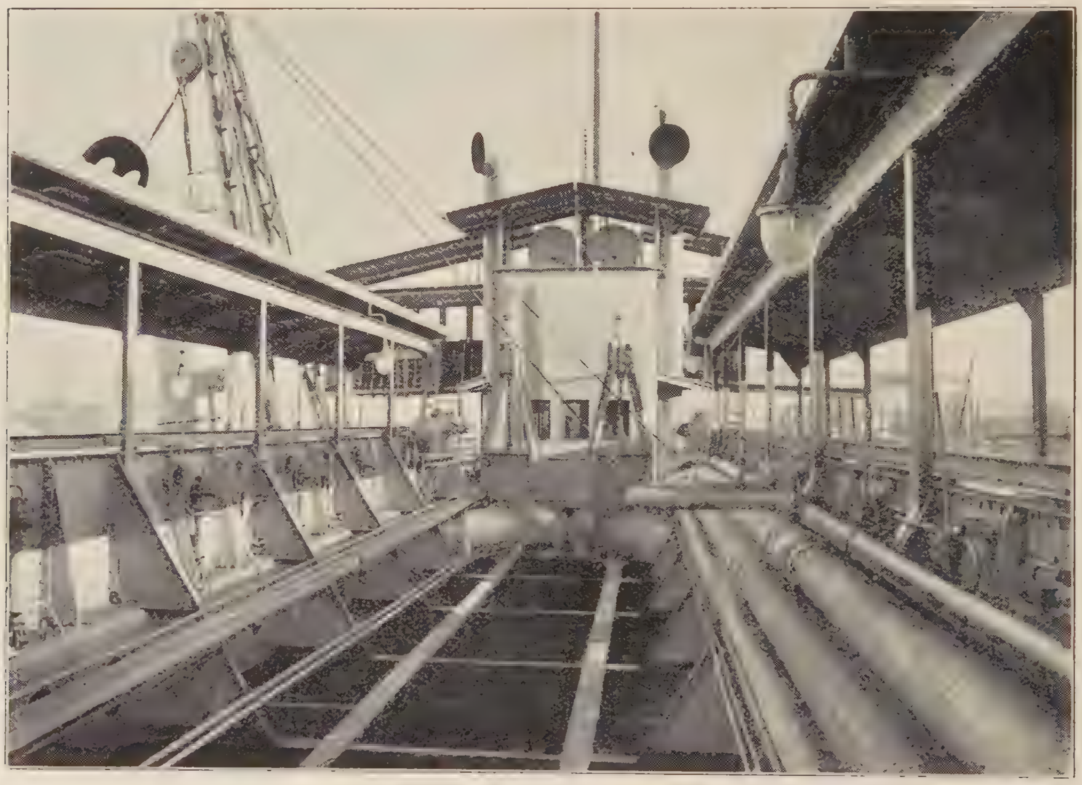


Fig. 111.

A condenser of the "Fyenoord" type with a steam-driven Weir's monotype air pump.

An independent centrifugal circulating pump.

A feed-water filter with a float gauge.

An automatic feed pump and an auxiliary feed pump on the "Voit" system, both of the same size.

A feed-water injector.

A feed-water heater.

An evaporator.

A duplex bilge pump.

Two duplex pumps for sanitary purposes, one for fresh, and the other for salt water.

All main engines have mechanically driven oil pumps and a central sight feed lubricator for the moving parts ; regulators which are driven direct from the crankshaft by means of gearing, revolution counters and turning gear.

The steam for both plants with their auxiliary machinery, etc., as well as for the machinery on deck and the steering-gear engine, is supplied by four cylindrical flue-tube boilers, built according to the regulations of the Bureau Veritas and the rules for the use of boilers in the Dutch East Indies.

Each of the boilers has a heating surface of 179 square metres, and a grate area of 5·54 square metres ; the working pressure is 12 k.g. per cubic metre.

The steam from these boilers is first collected in a joint steam collector of cylindrical shape. From here it is led to the two engine-rooms and the deck engines, and is admitted by means of valves which can be opened from the passages on deck alongside the boiler casing.

As may be seen from Appendix E, the coal bunkers are placed in such a way that the coals are conveyed through the coal shutters to before the furnaces, while the bunkers can be easily filled through the coal hatchways and the coal scuttles.

The steam-engine plant, with boilers and further appurtenances, was supplied by the Engineering Works Kinderdijk, at Kinderdijk.

On the deck the following auxiliary machinery is found :

On the forepart a steam anchor-windlass.

On the port side a steam winch for lifting the T-shaped pipe for loading the barges.

At the stern a steam anchor-winch for the rear chain ; this winch is also used for hoisting loads of up to 8 tons by means of a derrick attached to the rear mast, and for placing a motor boat in the davits.

All these winches have reversing valve gear.

The heavy suction pipe winch drives, by means of a worm transmission, the drum on which the hoisting wires of the suction pipe are wound.

This engine has reversing gear which is worked, as has been described above, by means of a hydraulic cylinder, which is operated by the dredger master by means of a regulating valve on the bridge.

The reversing valve of the winch is forced back into its middle position by a set of spiral springs.

The wants of the crew have been well looked after by supplying them with good accommodation.

The spacious captain's cabin adjoins the navigation bridge.

In the deckhouse beneath it there are the engineer's cabin and a messroom for twelve people ; a lift from the nearby pantry facilitates the serving of the meals.

Besides the pantry there are on the main deck : a storeroom, a galley, two w.c.'s, two bathrooms, and the entrance to the officers' quarters, which are below the main deck.

The latter, eight in number, are very airy ; they all open into a spacious central passage and are protected from mosquitoes by swing doors and portholes guarded by mosquito netting.

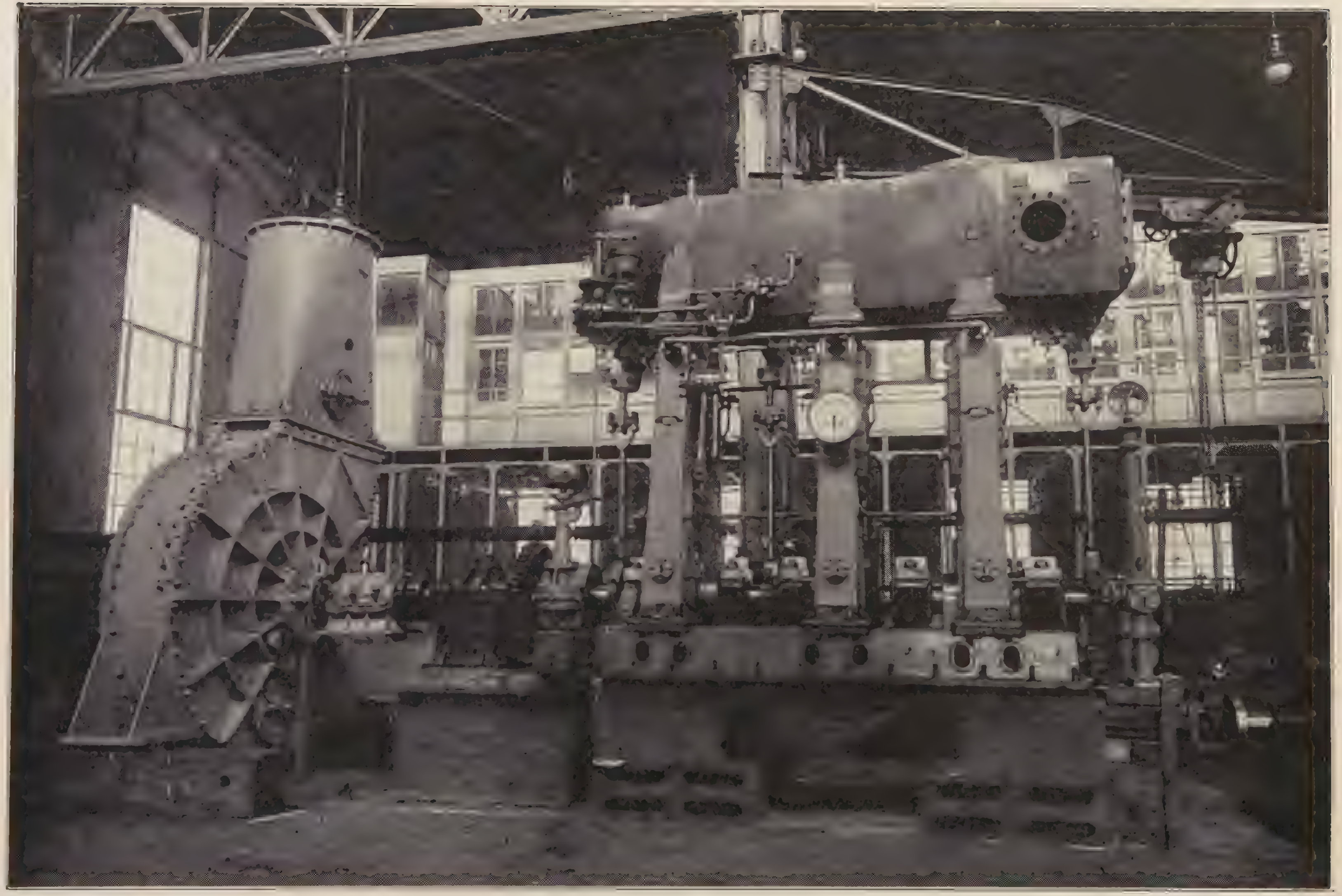


FIG. 112

The ventilation has been well seen to. In all cabins and apartments there are also electric fans.

In the deckhouse above the back engine-room there is a bathroom and w.c. for natives on one side, and a galley on the other side.

The accommodation for the natives is aft, below the main deck ; there is more than sufficient room in the five compartments set apart for them.

As may be seen from the various illustrations, a teak-wood roof covers the whole vessel to protect the crew from the tremendous heat and tropical showers.

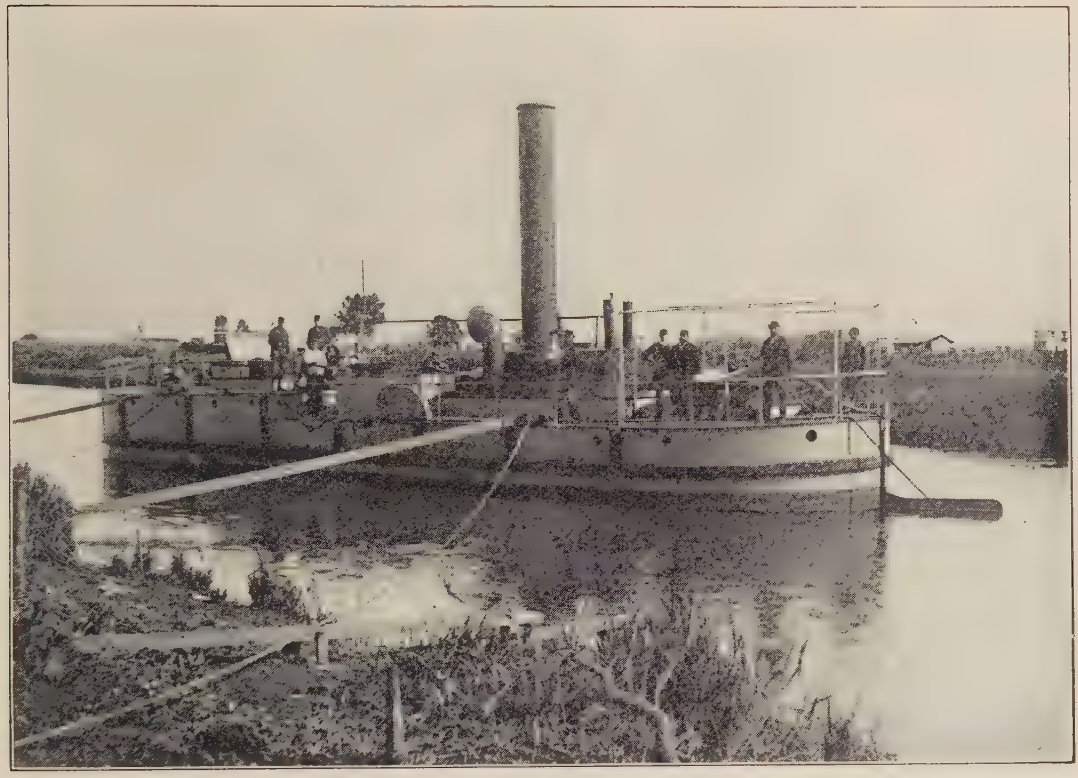


FIG. 113.

Favourable results having been achieved with this mud-suction dredger, two twin vessels, named the *Borneo* and the *Sumatra*, were ordered a few years later by the Dutch Colonial Department.

The chief dimensions remained the same, and the principal alterations introduced were as follows :—

Instead of two pump engines of 400 I.H.P. each, there is but one engine of 800 I.H.P., and consequently only one pump (Fig. 112). These dredgers, moreover, do not discharge themselves, which naturally makes the construction much simpler.

It had been proved by experience that the suction head could also be made with a single casing, as the water supply was found in this case to be unnecessary.

The boilers can not only be heated with coal, but also with liquid fuel, which is stored between the floor riders, just as on large sea-going ships.

So far, this class of mud-suction dredgers has not been built for private contractors, for the reason that these vessels can only be used in special places. Consequently, on this account, they are often lying idle, which is, considering the high cost of these appliances, a tremendous drawback from an economical point of view. They are, however, the very dredgers for governments, as they are the best that can be used in places where there is continual silting-up.

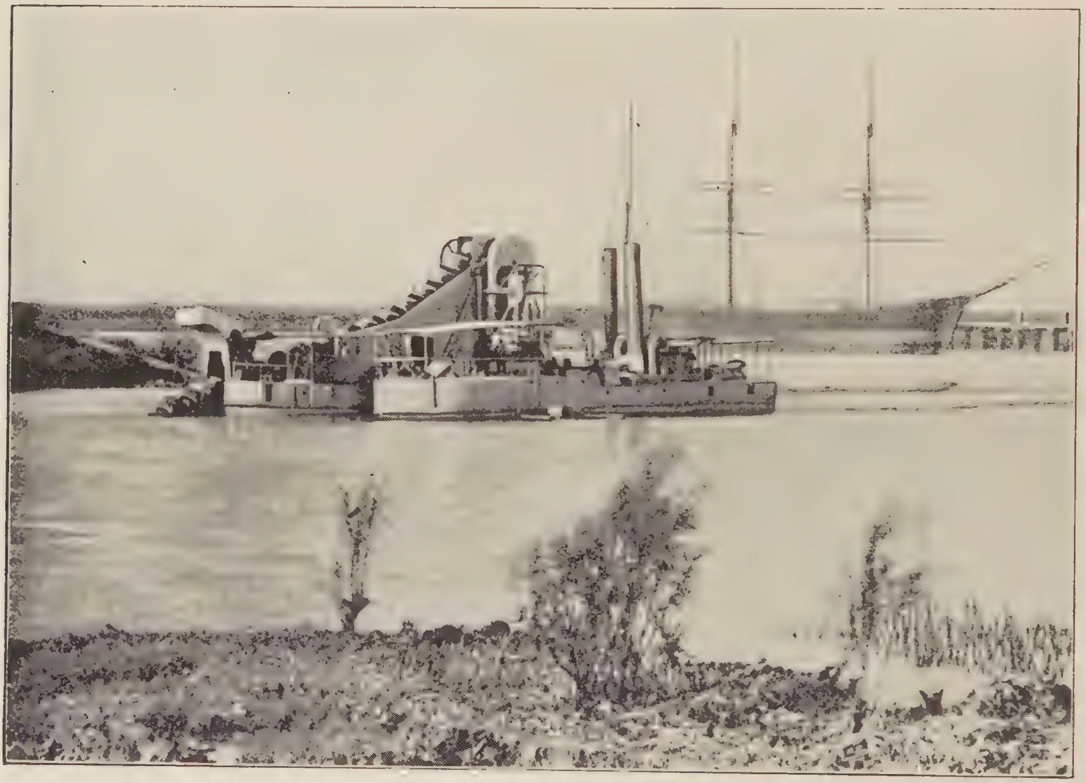


Fig. 113a.

FORCE-PUMP DREDGERS

To return to the first force-pump dredger, which has already been described; the following appliances were built in the year 1884 for the harbour works of the town of La Plata in the Argentine (Figs. 113, 113a).

Alongside a bucket dredger with buckets of a capacity of 250 litres a vessel was moored, which had a well in its middle, reaching to the top of the floor riders and into which the spoil of the dredger was discharged. Into this well a water-jet was led by means of a 25-centimetre centrifugal pump, while a two-bladed disc, driven by an independent engine, mixed the soil with the water. A 35-centimetre Dumont mud pump connected with this well drew up the spoil and conveyed it to the shore through a floating pipe.

Both water- and mud-pump were driven by a horizontal compound engine with condenser of 175 I.H.P. The transmission took place through belts.

The Dumont mud pump consists of a cast-iron casing like that of a water centrifugal pump, with a suction opening on each side, which are joined round the casing; the four-bladed disc has renewable blades and revolves between chilled-iron wearing rings (Fig. 114).

This method was used very successfully at La Plata, chiefly owing to the fact that the soil to be excavated consisted of a light kind of clay mixed with sand.

Some time afterwards some dredgers were built for the Russian Government. These dredgers had a similar force pump mounted on board. It was driven by a horizontal compound engine with condenser, while the bucket chain was driven by a similar engine.

The force pump had a suction opening in the bottom of the vessel, while the dredged material was conveyed to the interior of the suction pipe of the pump, so that, as with the first force-pump dredgers, the spoil was mixed and forced out with the water.

In the year 1905 an ordinary sand pump like that of the hopper is found on board the bucket dredger *Santa Fé*, which was ordered for the construction of the harbour works of the town of that name (Fig. 115).

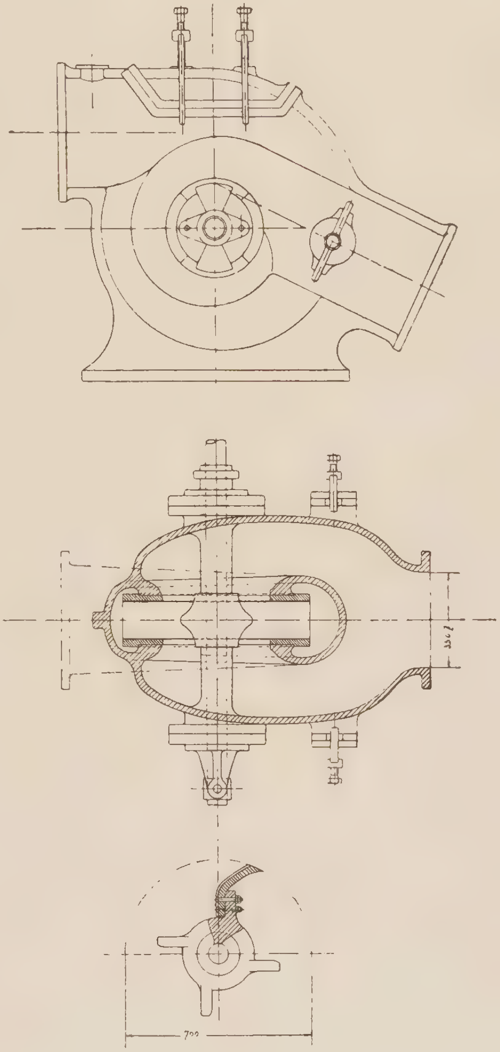


Fig. 114.

This vessel had the form of an ordinary ship with an open well in the forepart, and was built according to the regulations of the Bureau Veritas under special supervision and classed in the highest class (13/3 R.I.I.).

The chief dimensions are :

Length	46 metres.
Breadth on main frame	8 metres.
Depth on main frame	3·60 metres.

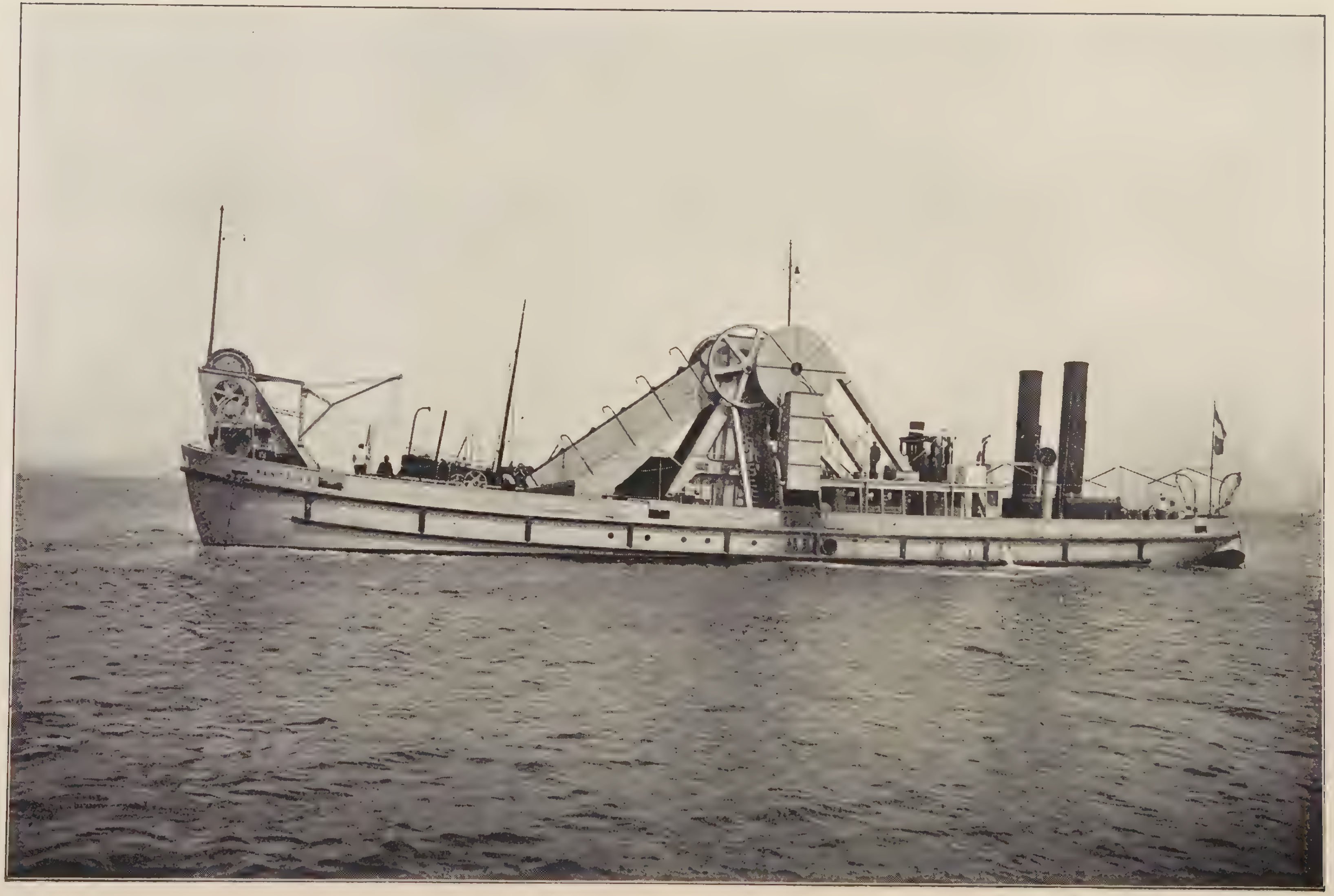


Fig. 115.

The dredging depth was about 11 metres, and the buckets had a capacity of 500 litres.

The bucket chain was driven in the ordinary way by a vertical triple-compound engine with its own surface condenser, developing 200 I.H.P. at 150 revolutions, equal to a speed of sixteen buckets per minute.

The force pump, which is placed against the end of the well, is direct acting, and driven by a similar engine of 350 I.H.P. at 175 revolutions.

The steam for both engines and all auxiliary machinery was supplied by two boilers of a heating surface of 100 square metres each, at a pressure of 12 atmospheres.

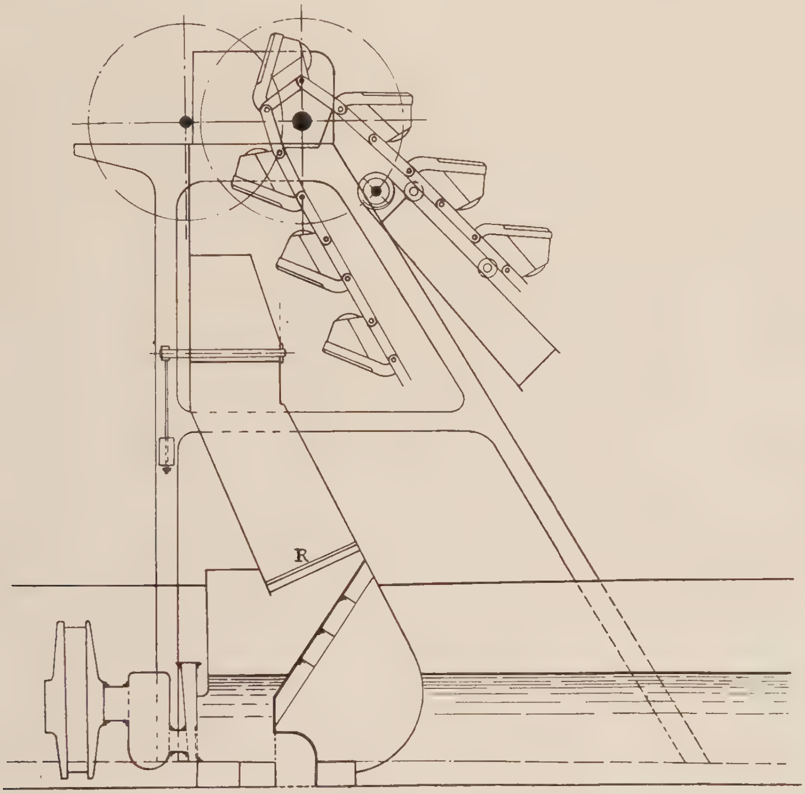


FIG. 116.

The spoil may be conveyed at will either to barges moored alongside the dredger, or discharged direct into the back part of the well, which takes the form of a separate reservoir. When the spoil is conveyed to the barges the process is the same as that observed in all dredgers ; in the second case the door in the shoot is placed in a vertical position and thus acts as a knife for cutting the soil ; the bottom plates of the fixed shoot are removed and used for closing the sides of the shoots, so that the spoil is conveyed direct to the reservoir mentioned above. Above this reservoir there is a grating R, consisting of removable steel knives, which serves to cut the spoil and to intercept large pieces of wood, etc. (Fig. 116).

A sluice valve in the forepart of the reservoir below the water level regulates the water supply. The dredged earth is mixed with the water that flows in ; is drawn up by the force pump, and conveyed to a distance of 300 metres and to a height of 8 metres above water level by a discharge pipe, 55 centimetres in diameter. The output is 300 cubic metres per hour.

The force-pump engine may be coupled to the pump, or to the propeller, as may be desired. This dredger successfully made the voyage to Santa Fé under its own power.

During the voyage the well was closed by a temporary bottom which could be removed without dry docking, as has already been described.

Finally we must mention a force-pump dredger of tremendous size, the *M.O.P.—C* 16, built for the Argentine Government (*vide* Fig. 56).

It is the ordinary type of sea-going bucket dredger, with an open well in the stern. On each side of the well there is a screw frame with a rudder post ; the two rudders are connected together. The propellers are driven direct by triple-compound engines of 450 I.H.P. each. Both engines can be coupled direct to a sand or force pump, so that they can either drive the pump or the propellers. As in the Santa Fé bucket dredger, the spoil can either be discharged into barges or into a reservoir ; the soil, mixed with water, is drawn up by a pump and conveyed to a second pump, so that the discharge is effected by means of two pumps working in series. The bucket chain here also is driven in the ordinary way by a triple-compound engine of 450 I.H.P.

This vessel, too, was built in accordance with the regulations of the Bureau Veritas in the highest class.

Its chief dimensions and the requirements it had to meet were :

Length	60 metres.
Width over main frame	11 metres.
Depth from main frame	5 metres.
Speed of vessel	15 k.m. per hour.
Dredging depth	13 metres.
Output	650 cubic metres per hour.
Capacity of the pumps	5,400 cubic metres per hour.
Total heating surface of the boilers	390 square metres.
Discharge distance	700 metres.
Discharge height	5 metres.
Capacity of buckets	1 cubic metre.
Diameter of discharge pipe	70 centimetres.
Speed in discharge pipe	a little over 3 metres per second.

Besides the complete steam-steering gear with which the vessel was equipped, the ship possesses an auxiliary boiler of 10 square metres heating surface, for driving the electric lighting generator, and a small electric power station for driving the necessary machinery used for repairing, each unit of which is equipped with its own motor.

DISCHARGE PIPE

Instead of floating wooden beams, ordinary steel pipes, closed at both ends, are now used as pontoons by which the discharge pipe is supported. To facilitate transport they are constructed in such a way that they all fit into each other, while the force pipe fits into the smallest floating pipe. A great saving in freight is achieved by this means (Fig. 117).

The leather joints are sometimes protected by an armour of steel wire-netting on the outside, both ends being provided with angle steel rings instead of the usual flat iron connection bars.

Frequently of late canvas-lined rubber bags have been used in preference to the usual type, although in a few cases a ball-and-socket joint of light construction has been adopted.

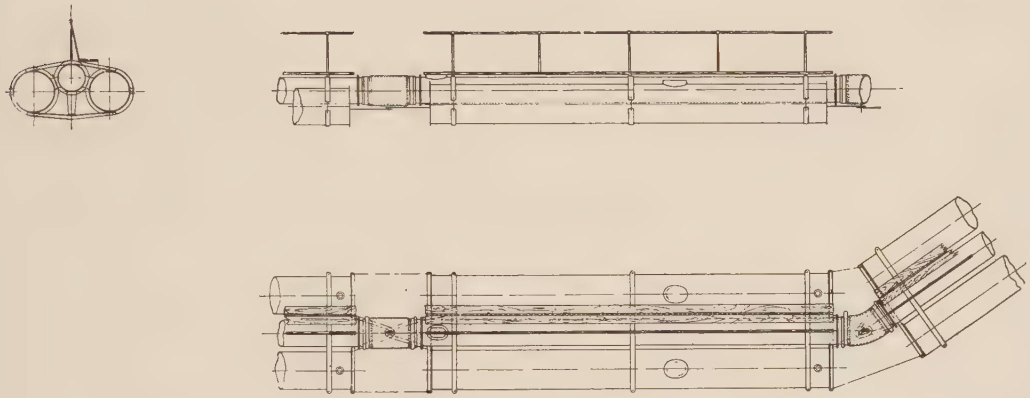


FIG. 117.

Ashore the pipes are joined together with flanges and packed with iron rings wound with greased string. A branch with a two-way valve is often used on the depositing ground so that the spoil can be conveyed in either of two directions, which is found very useful when the discharge pipe has to be extended, as this can be done without the work being suspended. Sharp bends should be avoided, and the discharge pipe should be raised to such a height that there is a slight, but continuous, slope towards the end.

BARGE-DISCHARGING SUCTION DREDGERS

In describing the elevator it has already been remarked that this appliance has almost been ousted by the barge-discharging suction dredger. The reason for this is, that the suction dredger can convey the spoil over a much longer distance than the elevator, the latter being restricted to fairly short distances. In many cases the deep-water depositing grounds had already been filled up by the hopper barges, and other suitable grounds raised by the elevator, so that circumstances made it necessary to find an appliance which could convey the spoil over greater distances to grounds situated at a greater distance from river or canal.

The term " barge-discharging suction dredger " sufficiently expresses how it works, viz., the emptying by suction of barges that have been loaded by means of a bucket dredger, a sand-suction dredger, or by some other method.

The first barge-discharging suction dredger (Fig. 118), called *Geopotes*, looked like an ordinary tug. She was bought in England by the firm of Volker & Bos, with the object of equipping her for the purpose of carrying out experiments in the Nieuwe Waterweg, viz., to suck sand from a barge and convey it to the shore by means of a force pump.

A sand pump, the suction pipe of which is led into the barge, is coupled to the engine. The suction pipe carries a brass stuffing box which can be lowered into the hold. On board there is a centrifugal pump driven by an engine of one cylinder. By pumping the water forcibly into the hold of the barge the sand is loosened, mixed with water, and is then drawn up by the sand pump and conveyed to the shore through ordinary discharge pipes. The sand soon settles, while the water flows back to the river.

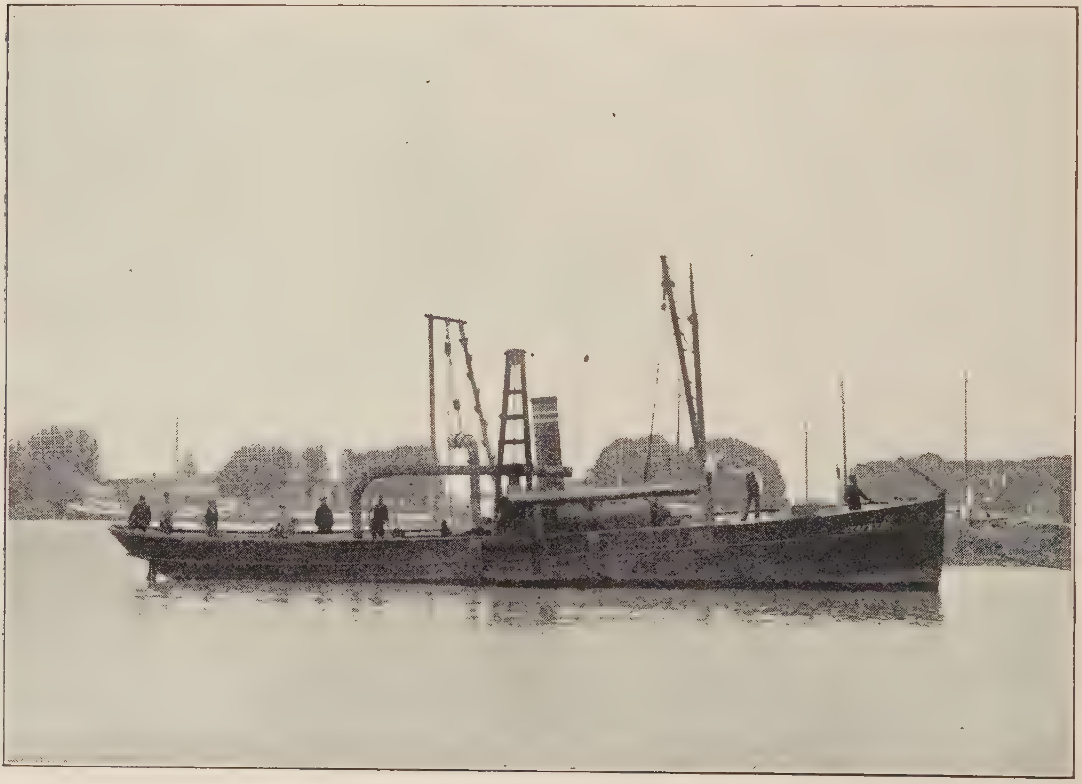


Fig. 118.

The greatest difficulty was to make the sand pump draw and deliver at once, as both suction pipe and pump are full of air when starting. An ordinary blower is of no use in this case, being impracticable and taking too much time. The difficulty, however, has been solved in an ingenious way by connecting the discharge pipe of the water pump with the suction pipe of the sand pump, and by placing a valve in this pipe, so that the water pump can fill both sand pump and suction pipe with water before starting the

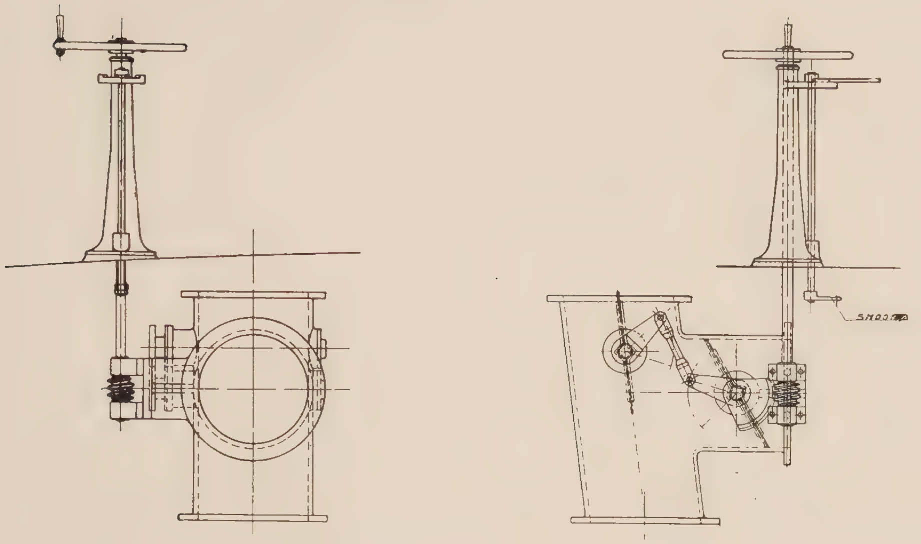


Fig. 119.

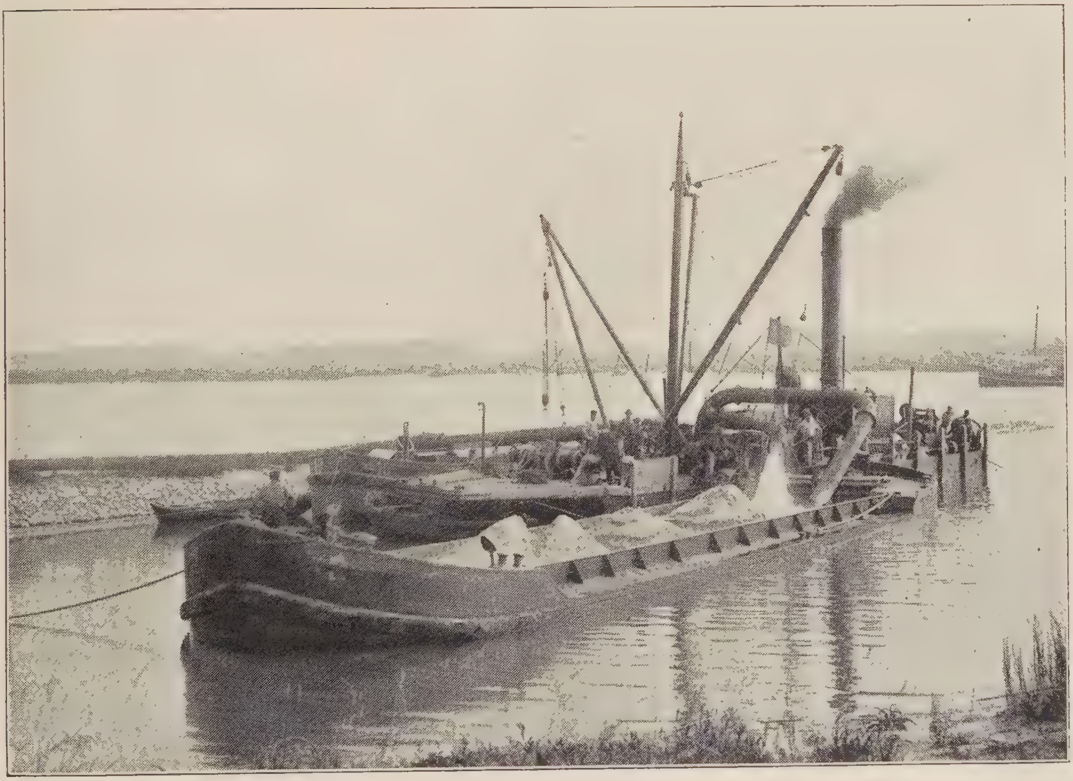


Fig. 120.

sand pump. Before long it was found necessary to place this valve as low as possible to ensure there being a column of water on the top, and thus prevent the ingress of air. Another improvement was the placing of a second valve in the discharge pipe of the water pump, which valve was coupled to the other valve in such a way that when one is open the other is closed (Fig. 119). In this way the air can be driven more forcibly into the suction pipe of the sand pump. It may be mentioned as an item of interest that with the approval of the inventors, a patent for this coupled valve motion was taken out and granted to Werf Conrad.

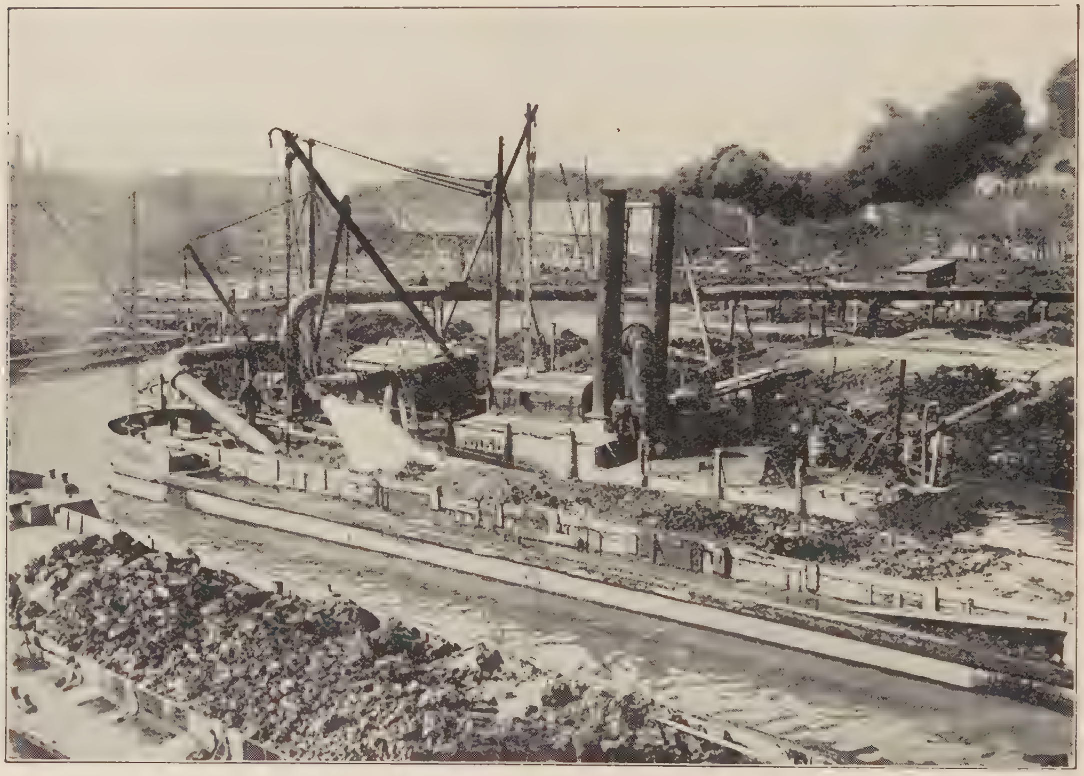


Fig. 121.

This first barge-discharging suction dredger had a suction pipe 35 centimetres diameter, and the sand pump was driven by a compound engine of 150 I.H.P.

The experiment was so satisfactory that even now this dredger is still being successfully used. It is not surprising, therefore, that it was soon followed by one of greater capacity called the *Lœvestein* (Fig. 120). The shape of this vessel was like that of a bucket dredger with a well in which the suction pipe was placed, so that it could pump sand either from the barge or from the river, while the discharge pipe conveyed the spoil to the shore or into the shoots, which, again, conveyed it into barges moored alongside. This process was very successful because river sand is coarse grained and

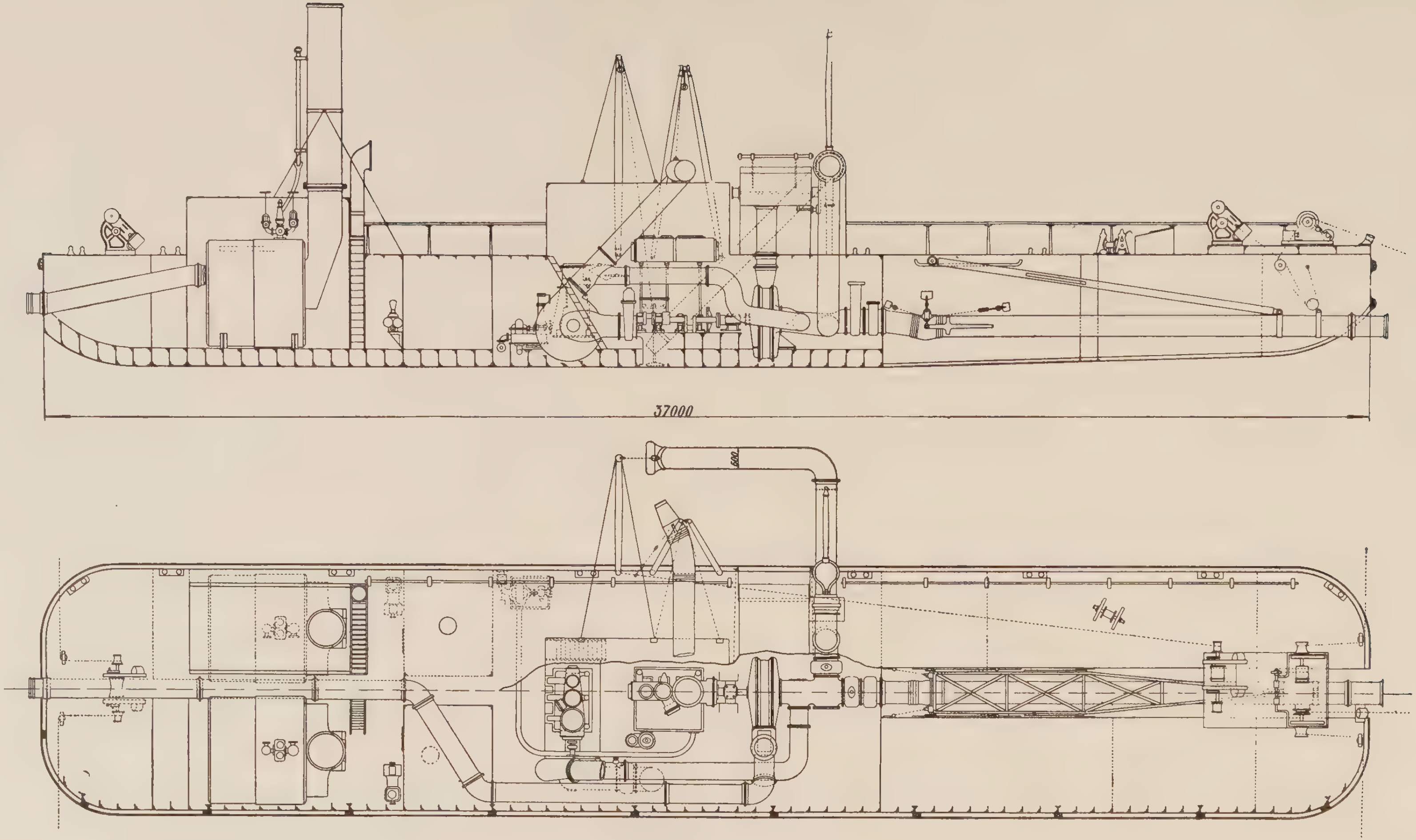


Fig. 122.

consequently settles quickly. It was demonstrated at the time that with this method more than 10 cubic metres of sand per minute could be discharged into a barge.

For the rest the equipment of this barge-discharging suction dredger remained pretty much the same, except for the main engine, which developed about 175 I.H.P., and the centrifugal water-pump engine, which was proportionally more powerful, while the suction pipe had a diameter of more than 40 centimetres. This barge-suction dredger was followed by the *Sliedrecht* (Fig. 121), with a suction pipe of 50 centimetres diameter and a main engine of about 300 I.H.P.

With this class of suction pump it was found that, as the diameter of the suction pipe became larger and the jet of water stronger, stickier kinds of soil could be dealt with and successfully dredged from the barges. Previously the removal of sand and light soils only had been attempted.

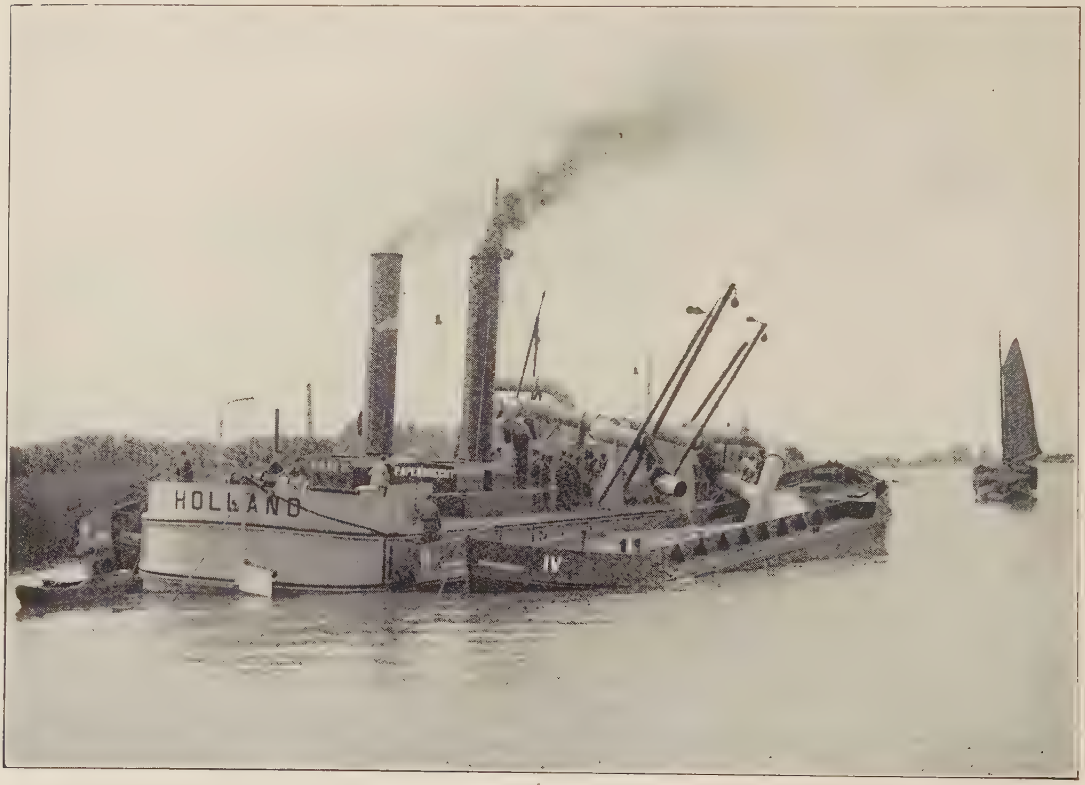


FIG. 123.

Next came the *Zuid-Holland* (Fig. 122), with a suction pipe 60 centimetres in diameter and a main engine of rather more than 350 I.H.P. The water centrifugal pump engine developed 150 I.H.P. Both are of the triple-compound system and are coupled direct to the pumps, this being now the common practice. Prior to that time accelerated transmission was applied by means of gearing on the sand pump, as at first it was feared that the disc might easily get stuck on stones, etc., with fast-running engines.

Several barge-suction dredgers of this type were built, and for a long time no new improvements were introduced. It is true that for foreign countries larger and more powerful appliances had been constructed, but they only differed from the above in their dimensions. It may be mentioned that the suction-pump dredger *Holland* was the first that worked with a jet of water either before or behind the suction pipe (Fig. 123).

The next improvement consisted in using two sand pumps coupled in series. The first pump empties the barge and conveys the spoil to the suction opening of the second pump; this then forces the material in whatever direction is desired. By this method not only is the action more certain, but the risk of the pumps failing becomes much smaller. Moreover, the pressure in the discharge pipe may be raised considerably, so that it becomes possible to force the spoil to a greater height and also convey it over a greater distance. These suction-pump dredgers, too, are equipped with a centrifugal pump with guide blades in order to produce a stronger jet of water to break up heavy and tough kinds of soil more easily.

That the speed in the pipes had been considerably increased may be readily understood from the fact that the heavy cast-iron pipes, that were used both for the suction and the discharge piping, were invariably scored and the steel plates badly stretched in those places where stones passed through the bends when working in soil containing many stones. For this reason these pipes were eventually replaced by cast-steel ones.

The height in the vacuum meter of the suction pipe varied from 40 to 60 centimetres, while at the suction opening of the second pump the pressure equalled nearly one atmosphere, or 15 lb. per square inch.

During the trials the pressure in the discharge pipe was raised to more than 2½ atmospheres. The connection with the shore was made by means of two sets of ball-bearing joints, one of which was on board and one on shore, the two being connected by means of a strong connecting pipe.

The first series pumps were driven by one engine only, but it was not long before each pump had an independent engine.

As the first of this kind we may mention the *Bayern* (Fig. 124), length 50 metres, width ± 8·50 metres, and depth ± 4 metres. It carries two sand-pump engines of 350 I.H.P. each. The pumps can work either independently or in series.

The water centrifugal pump engine has a capacity of 200 I.H.P. All engines are of the triple-compound system. Steam is supplied by three boilers with a heating surface of 100 square metres each and a pressure of 13 atmospheres.

When only one pump is working one of the boilers may be temporarily set down.

On board there is further a self-acting condenser plant for all the engines, winches and auxiliary machinery. The waste water is led into a tank through a filter, and a float automatically starts the boiler pump.

In order to give a clear idea of the high state of perfection to which barge-discharging suction dredgers have been brought, some particulars are given here of the latest two of these vessels, viz., the *Sliedrecht VI.* and *VII.* (Appendix F, Figs. 125, 125A).

These vessels can not only be used for discharging barges, but are also suitable for shaping ground to accurate forms, levels and slopes (profile dredger). The suction pipe of the *Sliedrecht VII.* is, moreover, furnished with a cutter, which led up to the cutter suction type of dredger.

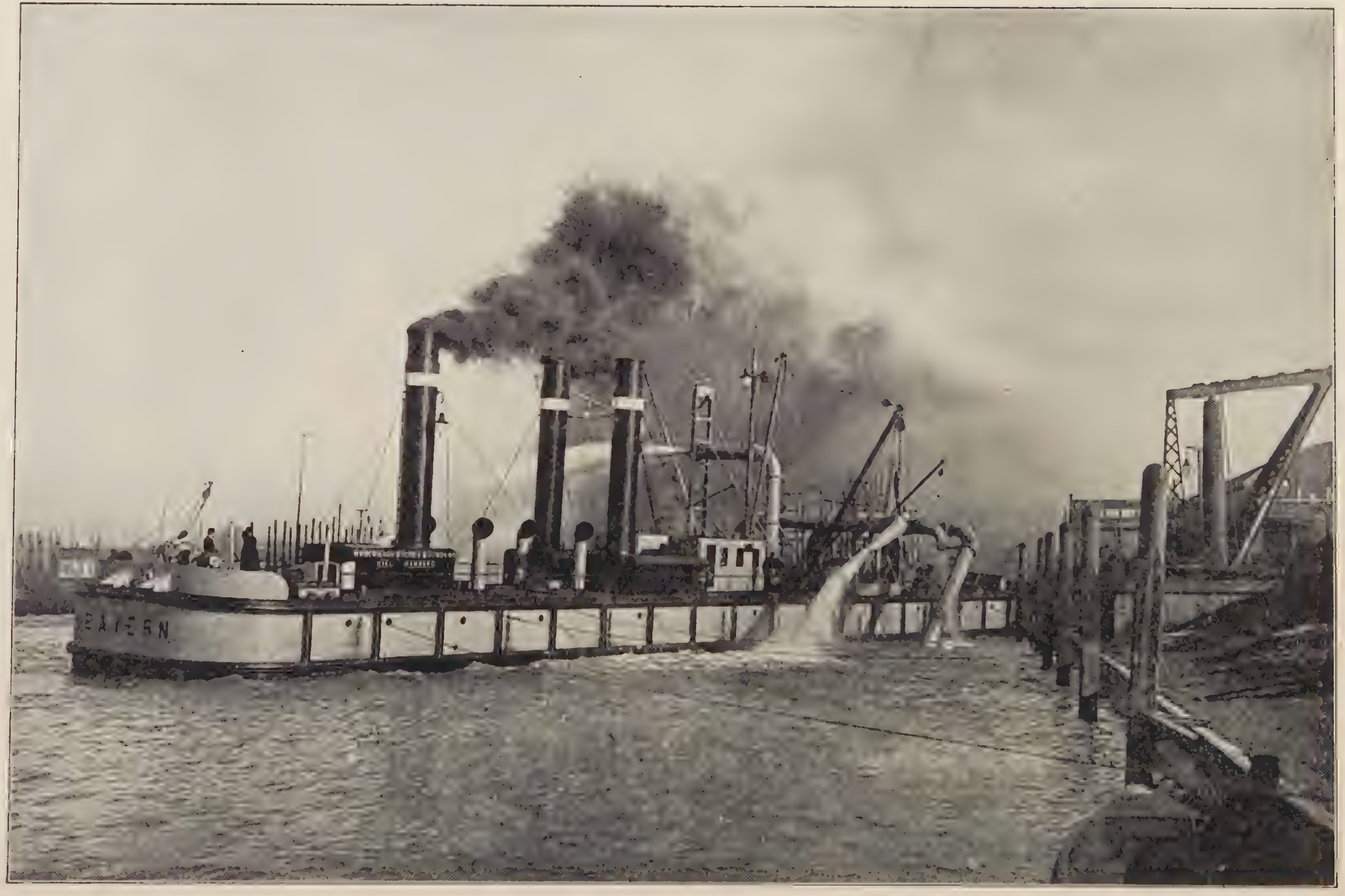


FIG. 124.

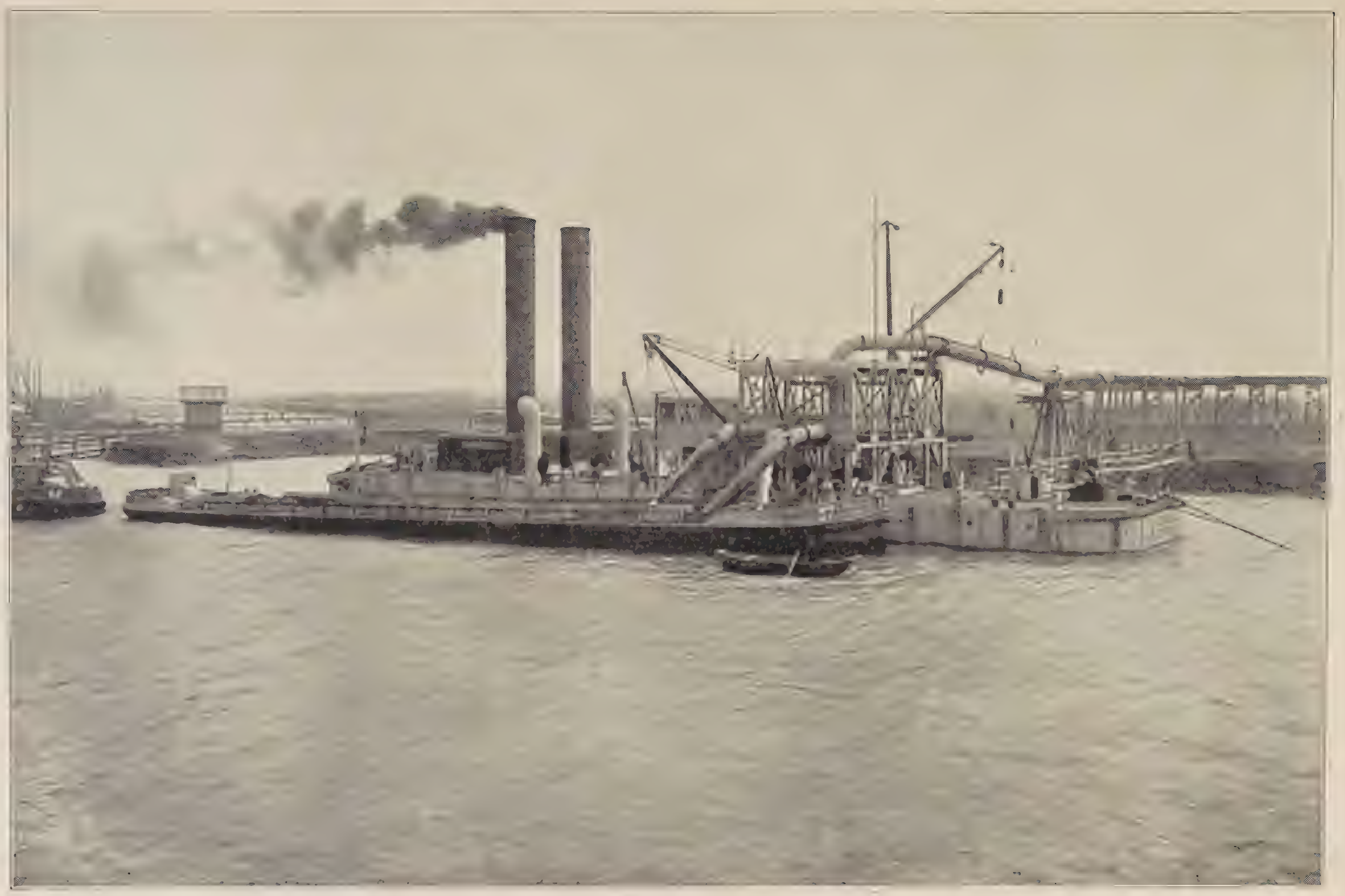


Fig. 125.

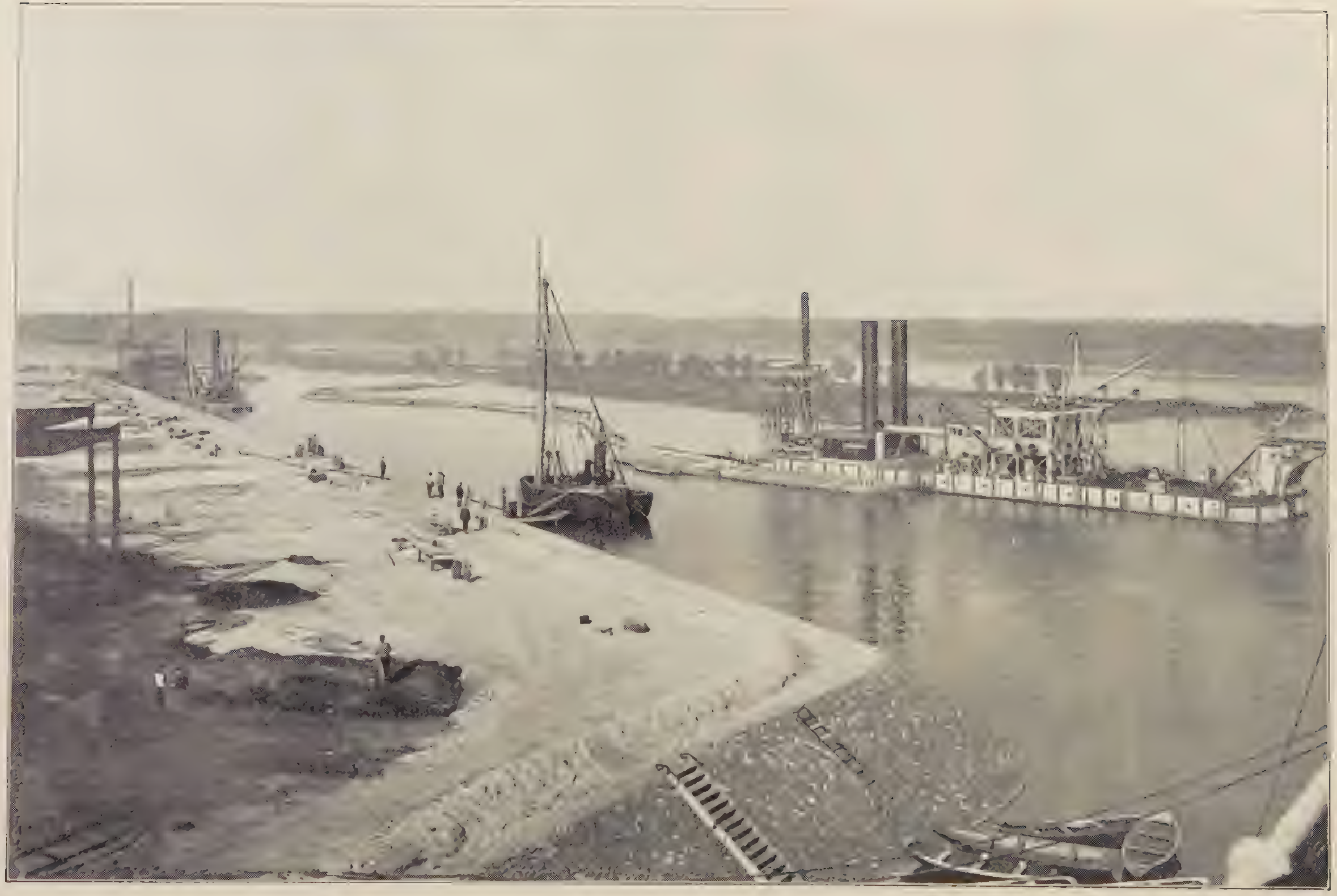


FIG. 125A.

The length of the vessel is 50 metres.

The width is 10·50 metres, the depth at the sides 3·80 metres, and in the centre 4 metres.

The well is 16 metres long by 2·50 metres wide.

The heating surface of the two boilers is 400 square metres.

The two sand-pumps which can be coupled in series are driven by two triple-compound engines of 450 I.H.P. each, at 170 revolutions.

The water-pump engine develops 300 I.H.P., at 260 revolutions.

Besides the above-mentioned engines and boilers there are :

A self-acting surface condenser.
A heavy ladder with suction pipe and appurtenances.
Two sand pumps, a centrifugal water pump with pipes.
Seven steam winches, four hand winches, and every other component required for a well-equipped dredger.

The arrangement of the ship is as follows :

1. Two watertight compartments for water ballast in the forepart.
2. Accommodation for engine drivers, etc.
3. Engine-room with pumps.
4. Bunkers and boiler-room.
5. Storerooms.
6. Accommodation for sailors.

Two metres above deck and over the barge-discharging suction pipe there is a bridgehouse for the dredger-master. Besides a speaking trumpet and a bell, there are in this cabin all the handles required for operating the dredger, either as a barge-suction dredger or a cutter dredger. The centrifugal water pump, which is driven direct, has a suction opening of 700 millimetres, a discharge pipe of 650 millimetres diameter, with a narrowed mouthpiece of 280 millimetres.

This pump can discharge 65 cubic metres of water into the barge at a height of 4·50 metres.

Both direct working sand pumps are coupled in series, but they can also work independently of each other to empty the barges.

The diameter of the discs is 1850 millimetres, and their width 350 millimetres.

The disc shafts are supported, as near as possible to the sand pump, by a steel bearing block, 500 millimetres long, while a countershaft with a thrust block is placed between the pump and the engine.

Behind each pump there is what is called a "stonecatcher" with which the suction pipe is connected. The stonecatcher has a large cover which can be easily removed, so that objects, which are drawn up and cannot pass, may be quickly removed. If only a few stones are drawn up they will probably remain in the stonecatcher, but if there are many the stonecatcher will soon become full and the stones will continue their way towards the end of the discharge pipe, as may be clearly seen from the accompanying photograph (Fig. 126).

Both suction and force pipe of the sand pump have a diameter of 650 millimetres.

A steam-driven dynamo with a capacity of 65 amperes and 110 volts, at a speed of 425 revolutions per minute, including a complete switchboard, supplies light for the interior of the vessel and on deck, so that the work may be continued at night.

In order to show to how great a height these pumps can raise the spoil it may be mentioned that the dykes which give admittance to the railway bridge at Hembrug, near Zaandam, have been raised by these pumps to a height of 13 metres above water-level. That the spoil can also be conveyed over a considerable distance has only lately been proved at Rotterdam, where the spoil was conveyed from the river as far as the Kralingsche Plas, which is at a distance of about 3 to 4 kilometres. This distance has since considerably been exceeded. We must not forget that when the sand is coarse-grained it is very difficult to convey it over a great distance, because coarse sand settles more easily than fine sand when the current is not very strong, so that there is always a danger of the discharging pipes being quickly choked entirely with sand.

FIG. 126.

It should be mentioned that there is an air-valve in the pressure pipe at its highest point, a valve which automatically admits air should the sand pump stop, which prevents the weaker pipes collapsing under the air, owing to pressure produced by the vacuum in the pipes caused by the spoil flowing off. An ordinary relief valve is sometimes fitted, but the simplest method is to rivet a plate-steel cover with an air-hole to the discharge pipe. In the cover there is a rubber ball which closes the hole when the

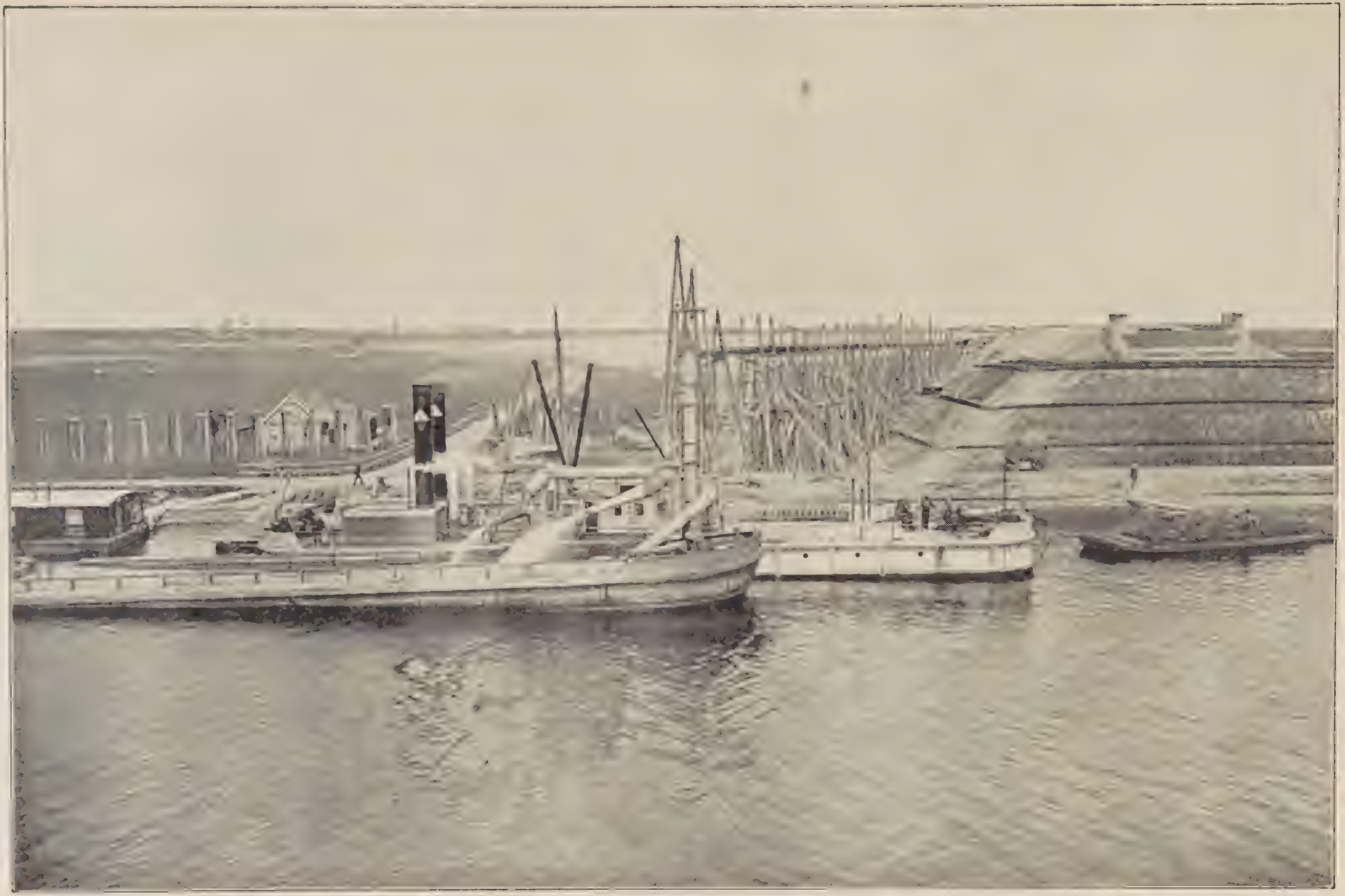


Fig. 127.

pump is working and falls down by its own weight when the pump stops, allowing air to be admitted through the opening (Fig. 128).

It will be clear now that if a barge-suction pump is to work satisfactorily one of the chief requisites is a very powerful jet of water, which can supply even more water than the sand pump can manage ; while one must also be able to direct the jet easily to wherever it is wanted in the barge. To attain this end the narrowed mouthpieces of the water-supply pipes are hung in booms, and are connected with leather joints to the fixed pipe. Further movement takes place through a hand and a steam winch.

In practice it has been found advisable to leave only a small space between the outer circumference of the disc and the casing of the sand pump ; while sharp bends in the suction and pressure pipes should be avoided.

As a rule the disc is three-bladed ; only very large discs are four-bladed.

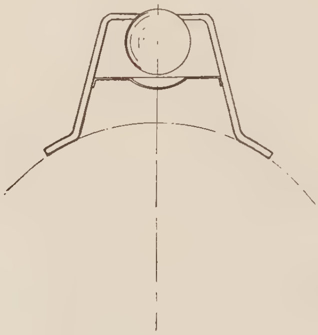


Fig. 128.

Experiments have been made with cast-steel closed discs of the same construction as those used in the water pump, but with the difference that the blades are of the same width both at the end and near the centre, to prevent the disc from getting jammed by stones, etc. Although the results were favourable the open disc is preferred in Holland, because it can be more easily renewed, and does not stick so easily when small objects get lodged between the walls of the pump casing and the disc. Large pieces of wood often revolve with the closed disc. A strong mast with boom (Fig. 128A) should also be on board, as it may often render good service as a hoisting gear.

One of the latest improvements which we may mention is the fitting up of two poles or spuds on the force-pump side of the vessel, which can be lowered as soon as the vessel has reached its destination, and which render the use of separate mooring bollards superfluous.

The doorless barges, which are emptied by these suction-pump dredgers, originally had a capacity of 100 cubic metres. That this capacity has been gradually increased is not surprising, and at the present time barges are usually used possessing a capacity of more than 250 cubic metres, while many have been built with a capacity of 300 cubic metres ; even 550 cubic metres has been occasionally reached (Fig. 129).

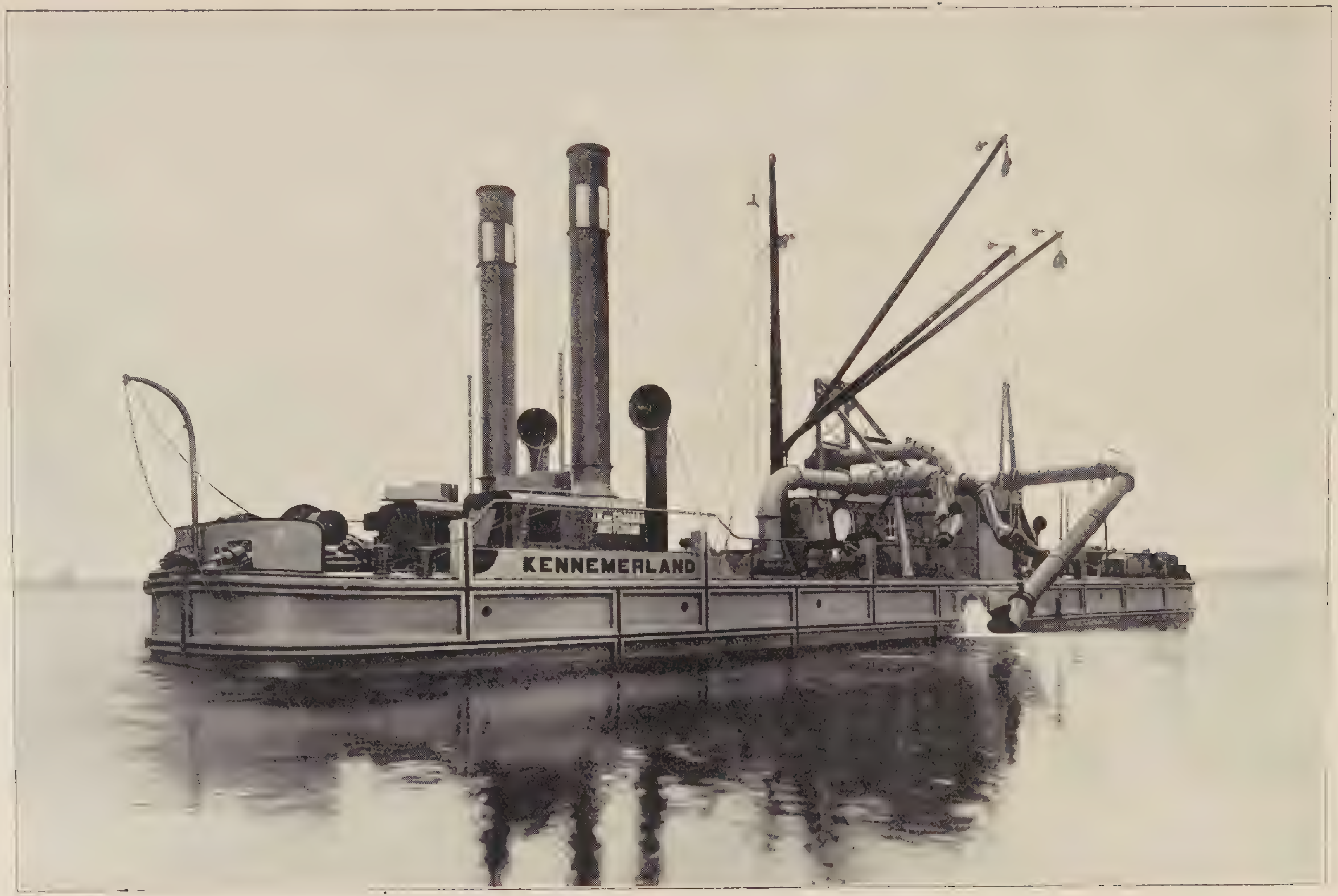


FIG. 128A.

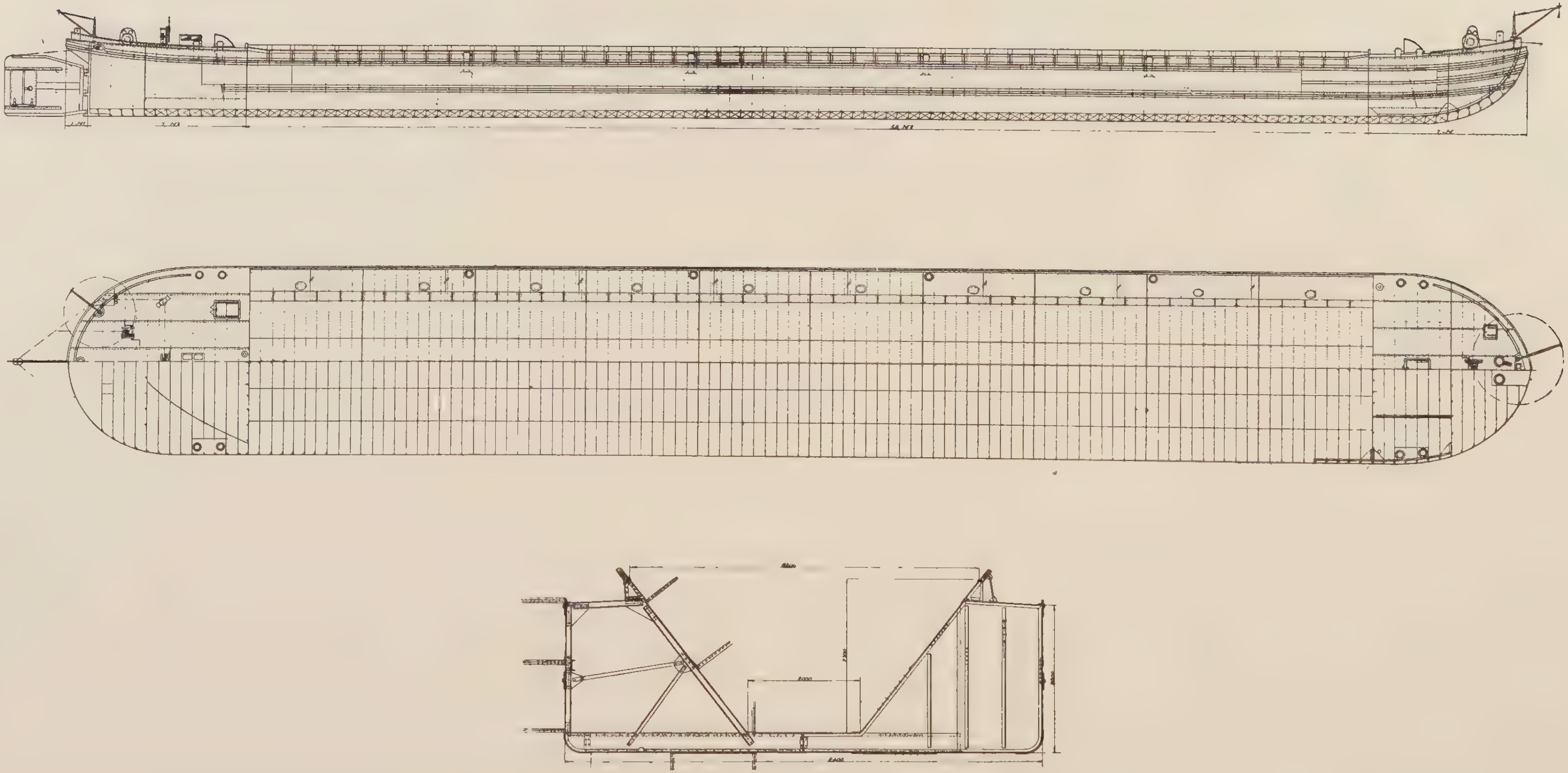


FIG. 129.

As regards the capacity of the barge-discharging suction dredgers, it will be obvious that this depends greatly on the nature of the spoil, but on an average we may assume that a barge of 300 cubic metres can be emptied by suction in about half an hour.

It may also be mentioned that attempts have been made to do without a jet of water by simply admitting the water to the barge by opening a valve, and also by building barges with a double set of doors, as has been already described, when discussing the self-discharging hoppers. The results, however, obtained with a powerful jet of water, both at the commencement of the operations and when dealing with heavy kinds of soil, are so favourable that it is not advisable to discard them for other methods.

CUTTER SUCTION DREDGERS

As far as the development of this class of dredgers is concerned Holland did not contribute much. They were introduced there after they had made a fair reputation for themselves in other countries, chiefly in North America. The credit of their introduction is due to the firm of Goedhart Bros., who, after having become acquainted with these appliances in North America, ordered the first cutter suction dredger in Holland. Several others followed, for instance, the *Simson* (Figs. 130 and 130A), while the *Sliedrecht VII.* may be mentioned as one of the latest of its kind. All these dredgers are fitted up as barge unloading suction dredgers, and they can also be used as profile dredgers, as the suction pipe for dredging from the sea-bottom carries a cutter at its lower end.

As mentioned earlier, first sand and afterwards mud were drawn up from the bottom, but with the introduction of the cutter suction dredger much heavier and tougher soils could be successfully raised.

The " cutter " is a knife placed in front of the suction opening in such a way that the knife cuts up the soil which is drawn up, and which is afterwards forced to the shore through floating pipes. It is plain that this method is very economical, as a single piece of machinery suffices to convey the dredged material direct to the depositing ground.

The idea of cutting up the soil and of drawing it up afterwards has already been commented upon in the description of the Bazin suction pump of the first hopper-suction dredger, though in this case the ground is not cut up directly by the suction pipe.

In a paper called " Dredging Operations and Appliances," by Mr. John Webster, M.Inst.C.E. (*Proceedings of the Institution of Civil Engineers*, Session 1886–87), we find a description of Schmidt's sand-pump dredger (Fig. 131), which had a vertical suction pipe that could be made to move up or down owing to its telescopic construction.

Over the opening a kind of horizontal milling cutter had been placed, consisting of a horizontal wheel, on the underside of which were attached a number of plough-shaped cutters, the wheel being driven from above by a vertical shaft. Over this cutter a hood was fixed, which just allowed the water to pass underneath, while to the top side of the hood was attached the suction pipe.

That this method had already been used elsewhere appears from the *Wochenblatt für Architekte und Ingenieure* for May, 1879, in which an article appeared, written by Herr Savels. He, too, draws attention to the economical way in which these cutter-suction dredgers work, and he gives a description of a small appliance of this kind with a suction pipe of only 0·26 metre diameter. The vessel was 27 metres long and 8 metres

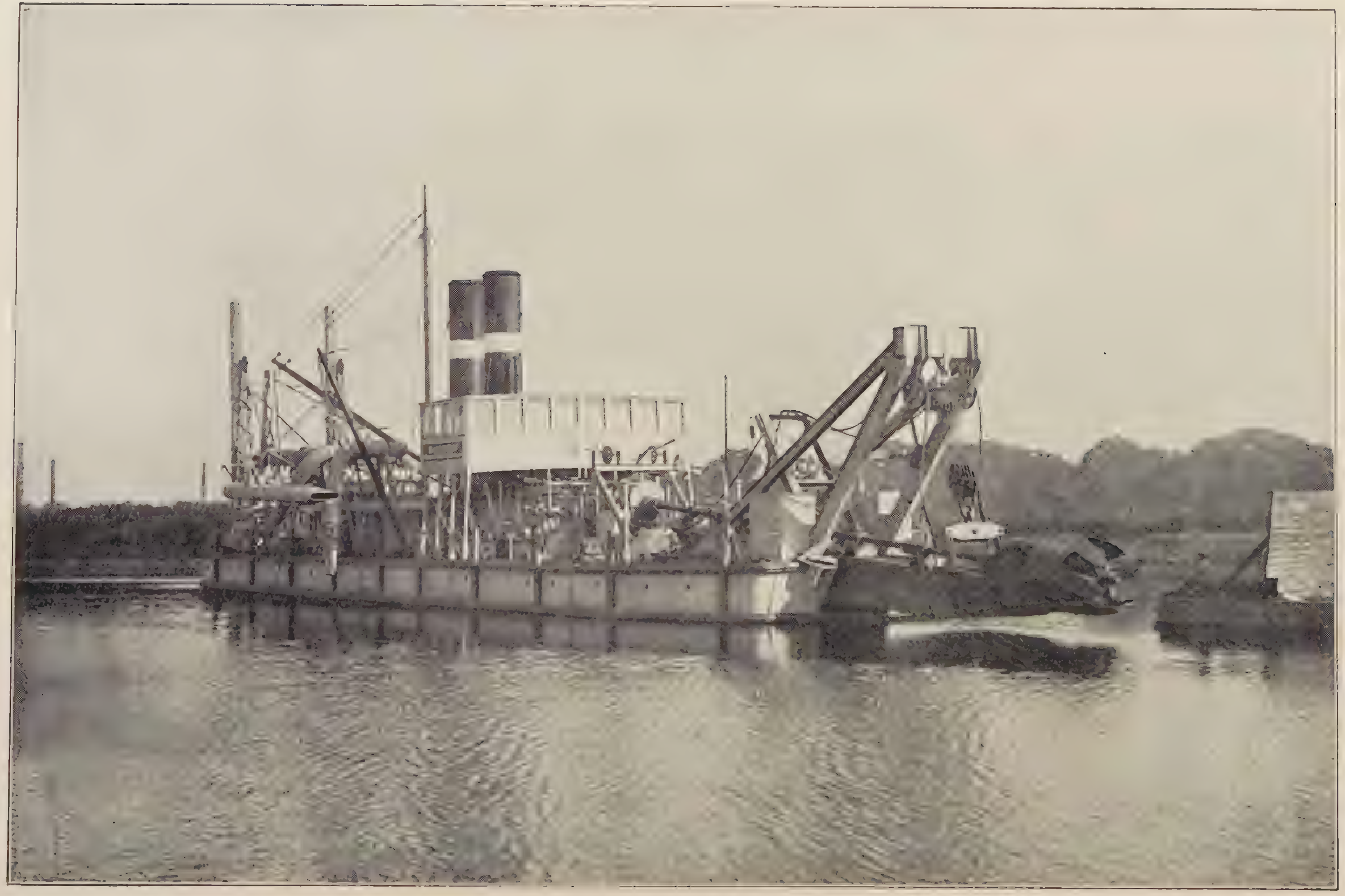


Fig. 130.

wide, while an inclined steam engine with condenser drove both pumps, the cutter and all the chains on deck (Fig. 132).

The sand pump had the ordinary form of a water pump, and the cutter was driven by the pump shaft. The capacity mentioned reached from 90 to 100 cubic metres of material per hour. It is certainly remarkable that as early as 1879 this method was already in use. This seems, however, to be quite an isolated case and nothing is known of further applications.

In North America the method has been applied to such an extent that the cutter suction dredger is as common there as the bucket dredger is in Holland.

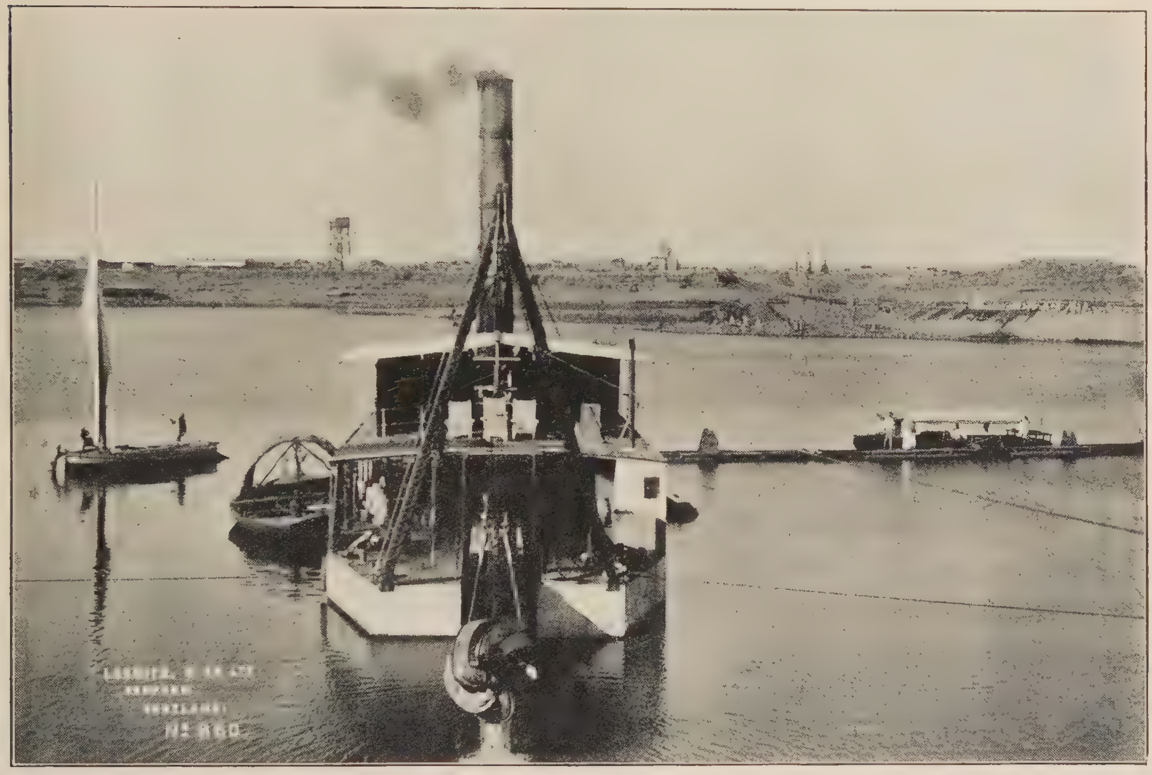


Fig. 130a.

There are two systems of cutters, viz., Bates's and Robinson's.

Both cutters make 10 to 15 revolutions per minute. The former consists of a cast-steel hub with five straight knives attached (Fig. 133), while the latter has five curved knives which are joined to a felloe at one end. The other ends are firmly keyed to a cast-steel hub, so that the whole has the shape of a basket (Figs. 134 and 134a).

An important part of the cutter suction dredger are the spuds by which the vessel is moved forward when the work is in progress. The spuds have taken the place of the bow wire and the stern chains, so that besides the spuds we now find only the two front side-chains or wires.

The spuds, which are two in number, are placed at the stern, and consist of two strong piles carrying a hard-steel point, and can be lowered into the soil by their own weight.

One of these is situated a little to starboard, the other a little to port of the centre line of the vessel. The way they work is very simple. When the starboard front chain is hauled in the starboard spud is down, and as soon as the end of the pitch is reached the port spud is lowered, the starboard spud raised, and the port chain hauled in. Proceeding in this way, the ground is cut up and afterwards drawn up and discharged by means of the floating pipes.

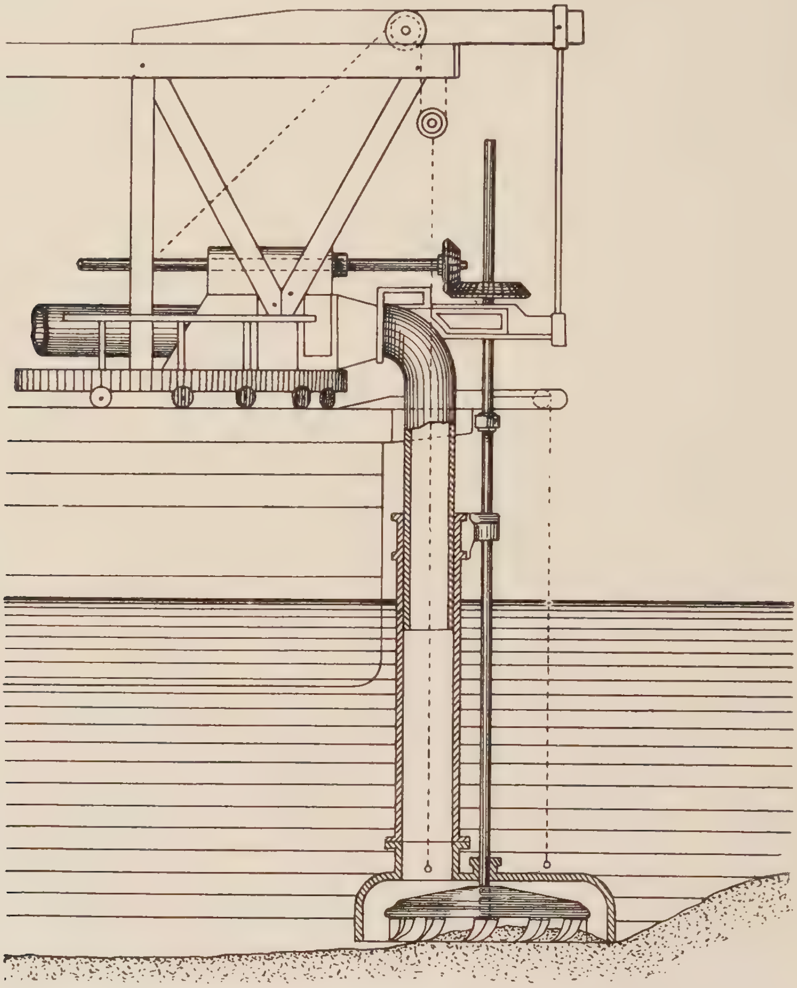


Fig. 131.

The drawback of this process is that the pitch always becomes wider towards the end ; hence a method has been adopted whereby one spud is placed in a groove in which it can move to and fro in the longitudinal direction of the ship. When cutting the fixed spud is always down in the bottom, while, the end of the pitch having been reached, the other spud only serves to move the fixed one so far forward as is required for cutting up the ground that has to be dredged. Each time the end of the pitch has been reached, the spud is let down in the groove, the fixed spud lifted, after which the spud, acting like a jackscrew driven by steam power, is moved so far backward in the groove as is required for cutting up new ground. Then the fixed spud is dropped again and the other spud is lifted. It is true that in this way we do not get a pitch of equal width, but its introduction is a decided improvement.

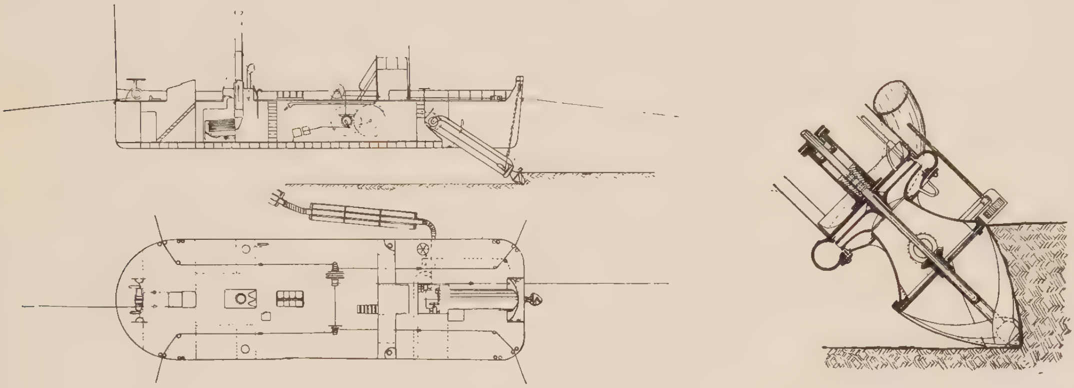


Fig. 132.

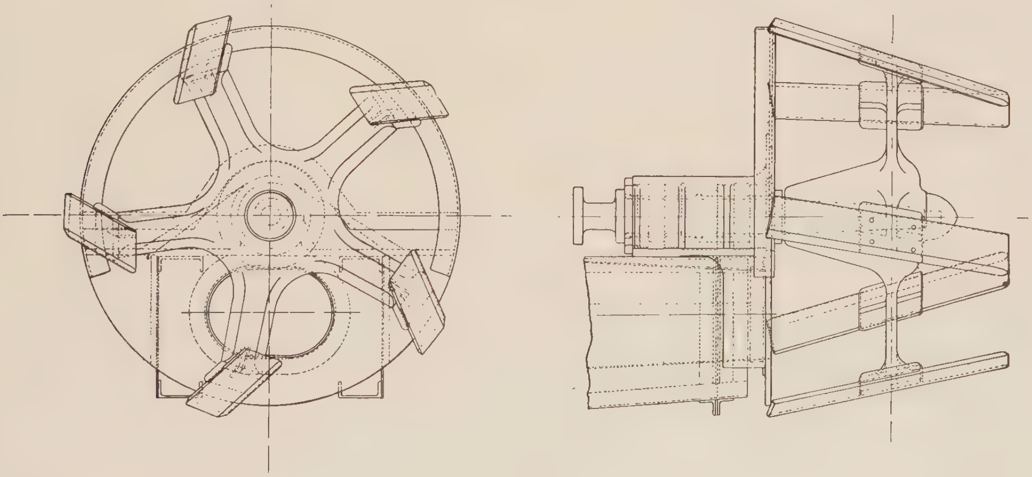


Fig. 133.

This method has still further been improved by Mr. Alfred Watkins, M.I.N.A., M.I.Mech.E., who has invented a way to make a pitch of fairly equal width ; the fixed spud, being placed amidships, is always advanced in the line of advance.

Mr. Watkins used two spuds which are lifted and lowered in the way that has been described, but one of the spuds is worked through a tube set eccentrically in a rotor at a suitable distance from the centre of the latter, and is consequently termed the "rotor spud." The other spud is only used as a pivot, round which the dredger is swung, and is called the "pivot spud."

The rotor has on its outer circumference a worm wheel which gears in a worm, the latter being actuated through gearing by the engine. By turning the rotor the centre of the spud carried in the rotor can be moved into the line of advance without regard to the axis of centre line of the dredger. The rotor spud being then dropped, and the fixed spud raised, the dredger can be moved in the required direction, and also to the required pitch of cut, by revolving the rotor.

Mr. Watkins applied his invention for the first time to the cutter suction dredger *Tilburian*, built by the Tilbury Contracting and Dredging Co., Ltd., a description of which appeared in *Engineering* for August 15th, 1913.

Ir. F. Smit, M.E., M.I.Mech.E., of Kinderdijk, again thought of a way to improve on this construction by placing both spuds in the rotor. Its great advantage is that when the work is in operation both spuds can be dropped, while the ship moves round the outer circumference of the rotor (Fig. 135).

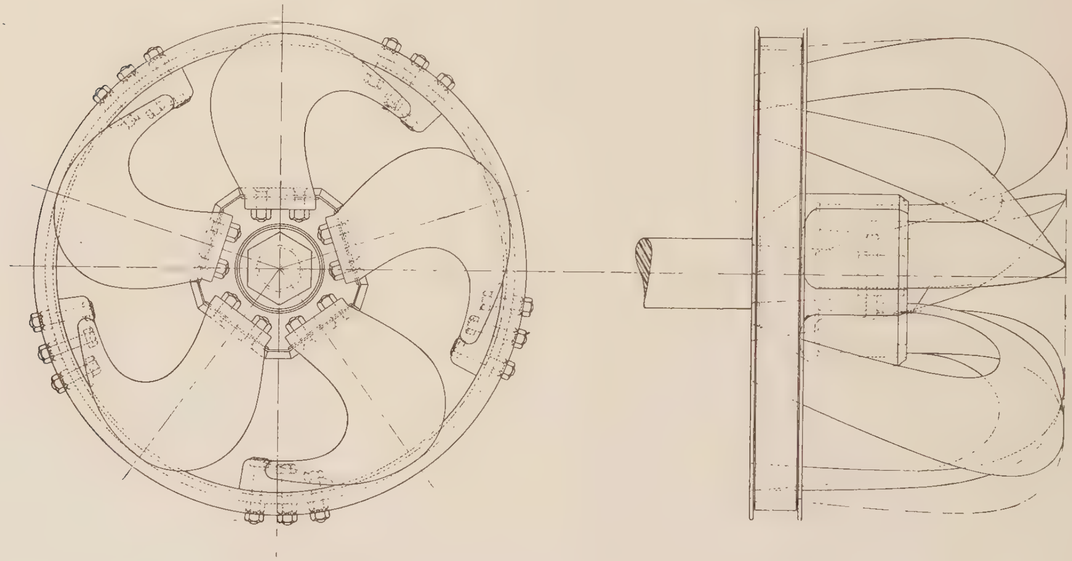


FIG. 134.

The danger of the spuds breaking or bending not only becomes much less, but at the same time a pitch of equal width is easily attained. A patent was applied for for this invention, but was not granted as the Watkins Patent already covered the possibility of using two rotor spuds.

Originally, only wooden piles were used for spuds in America; now they are usually constructed of steel.

As bending or breaking of the spuds is a very common occurrence, they should be easily renewable.

In conclusion it should be mentioned that many people prefer the cutter engine to be placed directly on the ladder and to be of such capacity that the cutter can easily cut its way through the heaviest soils.

Amidships there is a pilot-house, from where the captain can direct the various movements of the vessel as well as those of the spuds, and adjust the suction pipe; and from where, at the same time, he can survey the whole work and signal to the engine-room. In England cutters combined with suction hoppers are already used, as shown in Fig. 134B.

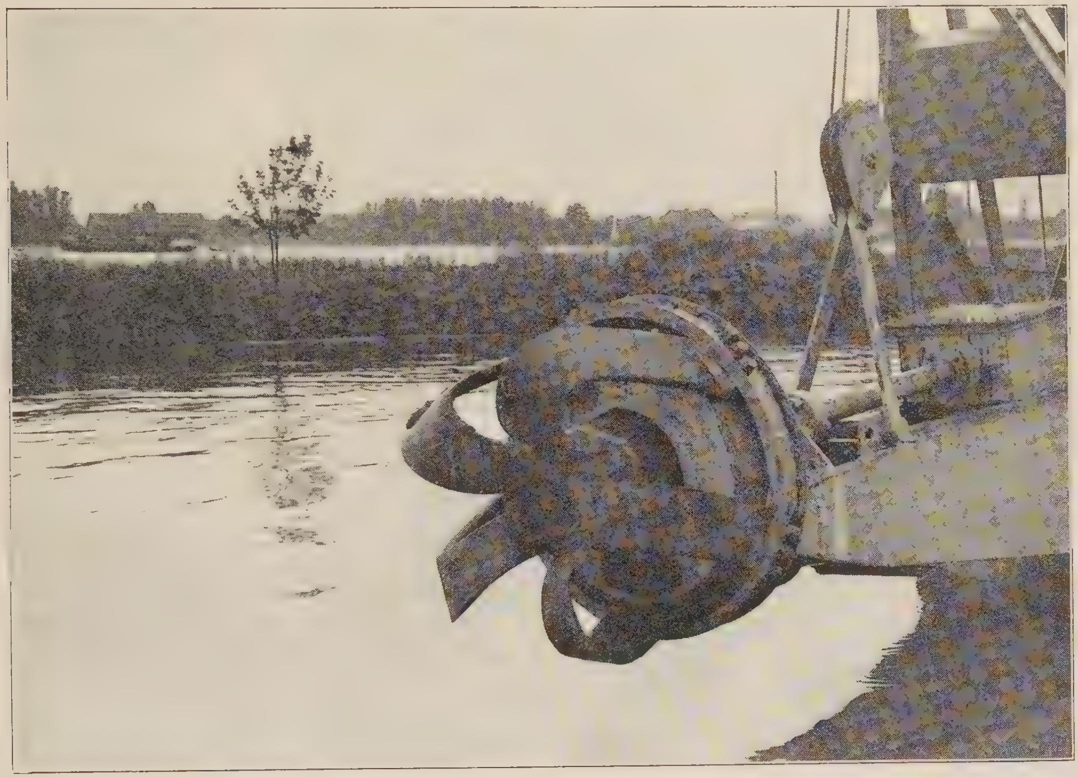


Fig. 134A.

MOTOR DRIVEN CUTTER SUCTION DREDGER

Though we have now come to the end of the history of dredging appliances reaching up to the present day, we must still mention an important order of the Hollandsche Aanneming Maatschappij given to I. & K. Smit's shipyards, for the construction of a barge-discharging cutter suction dredger, which is to be driven by internal combustion motors (oil residue), and which may be considered as the first trial in this direction as applied to a powerful modern dredger (Appendix G).

It is mainly the driving power which distinguishes this vessel from her predecessors, and involuntarily our attention is drawn to the motors that are to drive the two sand pumps and which may work either in series or independently.

Each sand pump will be driven by a vertical six-cylinder, four-cycle Diesel motor,

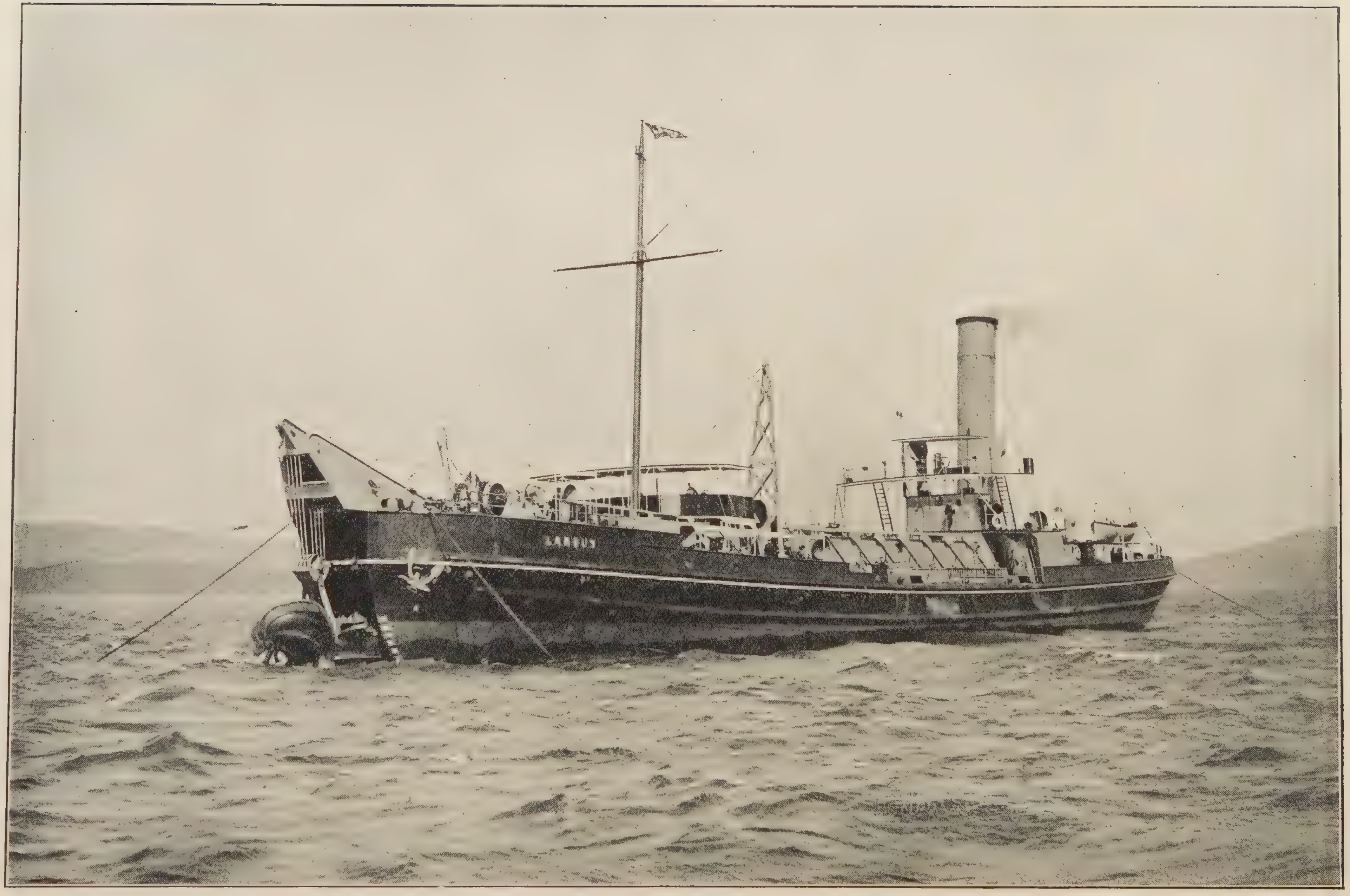


FIG. 134B.

without compressor, developing a power equal to a steam engine of 350 I.H.P., at 199 revolutions per minute.

The motors will be equipped with a fuel injector without air spraying; the fuel being forced into the cylinder by an atomiser.

The chief dimensions will be: diameter of cylinders 345 millimetres; stroke 500 millimetres.

The cylinder blocks have separate cylinder linings, and are placed direct on bed plates, and secured by means of steel anchors.

The valves in the cylinder covers are actuated by levers and bars with rollers from a camshaft, which is driven by the crankshaft by means of straight-toothed wheels.

The cooling of the cylinders and cylinder covers is effected by means of cooling water pumps attached to the engines.

The lubrication of all moving parts is carried out automatically by circulating oil under pressure, which is drawn up from the reservoir by means of a gear pump and forced into the piping.

The injection of fuel is brought about by means of a separate fuel pump for each cylinder driven by the camshaft. The speed regulation depends on the duration of the fuel injection, while an adjustable regulator prevents the maximum from being exceeded.

A hydraulic "Vulcan" coupling is placed between the motor and sand-pump shafts, the invention of Prof. Dr. Ing. Föttinger, of Berlin, the power being transmitted by means of oil with which the coupling is filled.

The oil required for the coupling is supplied by a separate pump driven by an electric motor cooler and electrically driven circulating pump, and flows back again to a reservoir, from where it is pumped through the cooler to the filling tank of the couplings. The latter can thus be filled or emptied in a few minutes.

The circulating pump is also used for providing water for washing the deck and as a reserve water-cooling pump for the Diesel motors.

The couplings have thrust blocks on both sides, the dimensions of which are more than sufficient to resist all axial pressures, those of the sand-pump shafts included.

At first, only the motor is started; next the coupling is filled with oil, which causes the sand-pump shaft to begin to move in such a way, however, that there is always a certain amount of slip between the motor and the pump shafts. The oil acts as a cushion in case the disc should stick and thus prevents serious damage.

It is clear, especially with a first experiment, that such a safeguard is necessary in order to find out whether the construction can afterwards be simplified.

The engine for driving the centrifugal water pump is a three-cylinder Diesel motor of the same construction and cylinder dimensions as the main engines, so that, all three engines being of the same size and design, the same spare parts may consequently be used for all three.

This engine will be able to develop a power equal to a steam engine of about 250 I.H.P., at 280 revolutions.

A direct-driven cast-iron centrifugal pump, with guide blades and a cast-iron disc, is coupled to this engine. It will be possible to discharge through its narrowed mouthpiece about 55 cubic metres of water per minute at the desired height into the barge.

The suction pipe and discharge pipes will have a diameter of 600 millimetres.

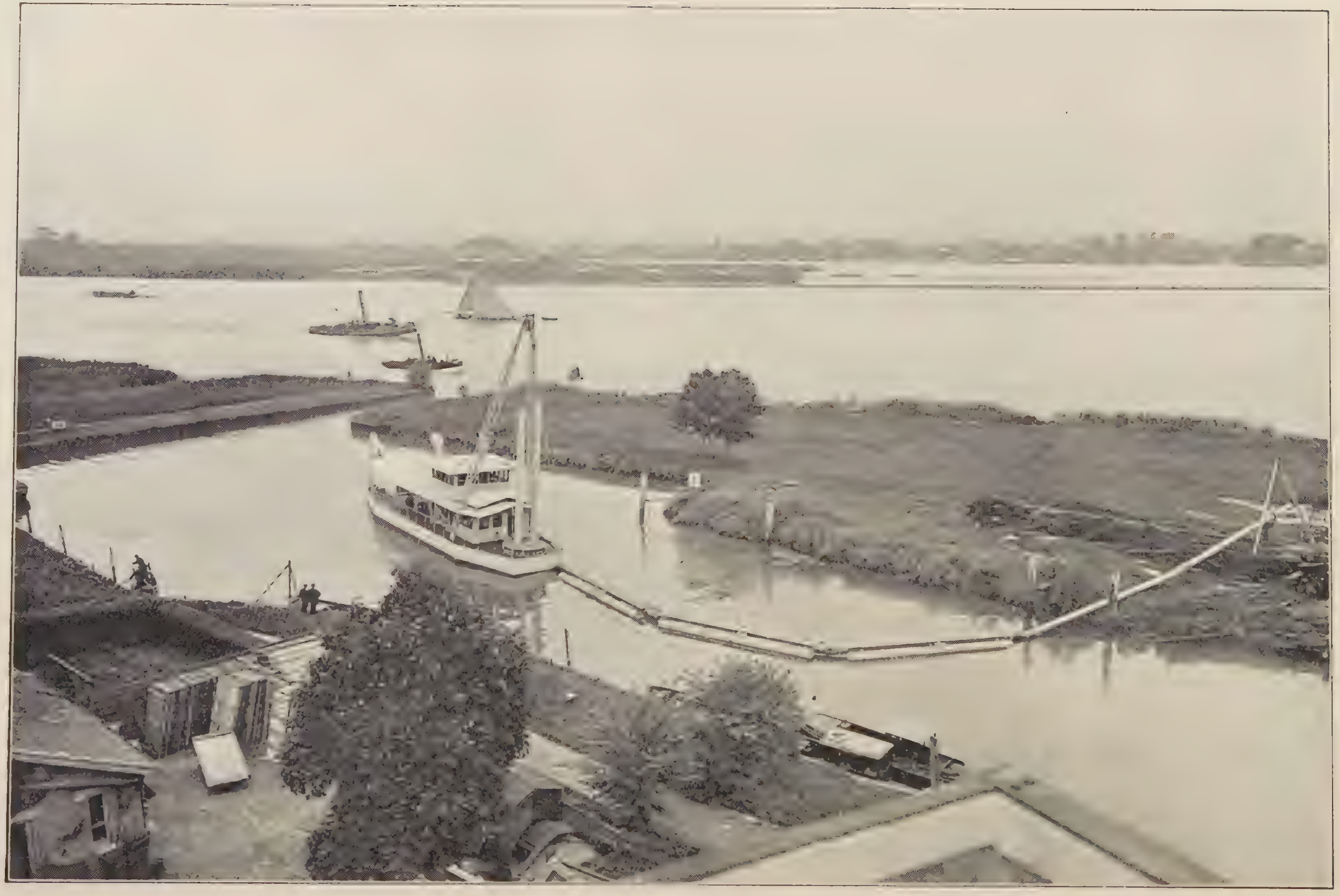


FIG. 135.

A thrust shaft, with thrust bearing and friction clutch for temporarily disconnecting the pump, when the vessel is used as a cutter suction dredger, will be placed between the engine and the pump shaft.

Between the Diesel motor and the centrifugal pump a continuous-current compound dynamo of 150 k.w., 220 volts, with removable bushes, will be placed to supply the current required for the electric motor mounted on the cutter ladder. A switchboard is provided so that current from the dynamo can be used as a reserve power for driving the winches and auxiliary machinery when necessary.

A three-cylinder Diesel motor of the same construction as the three engines, described above, but with a cylinder diameter of 260 millimetres and a stroke of 360 millimetres, developing 125 brake horse-power at 350 revolutions per minute, will be coupled to a dynamo of 85 k.w. of 220 volts pressure, and will supply the current required for the central winch, the ladder winch and the other auxiliary machinery.

To the shaft of the dynamo an air compressor of a capacity of about 52 cubic metres per hour will be coupled for filling air receivers used for starting the engines.

Each of the four Diesel engines mentioned will be equipped with a large lubricating oil cooler.

A one-cylinder Diesel motor of 12 brake horse-power at 500 revolutions per minute, with a cylinder diameter of 150 millimetres and a stroke of 200 millimetres, will drive a dynamo of 6 H.P. for lighting the vessel. An auxiliary compressor of a capacity of 15 cubic metres per hour will be coupled to the shaft of the dynamo by means of a friction coupling. This motor can be started by hand without the help of compressed air.

There will also be an electrically driven bilge and ballast pump for filling and emptying the water-ballast compartments in the forecastle.

A 100-millimetre centrifugal pump with an electric motor will act as bilge pump for the sand-pumps compartment.

Three high-pressure centrifugal pumps, each coupled direct to an electric motor, will supply the water pressure for the packing space of the sand pumps and the cutter block.

There will also be a small fuel pump driven by an electric motor for filling the day tank from the fuel reservoirs.

The cutter is to be driven by a 220-volt electric motor of 180 H.P., at 600 revolutions, mounted on the cutter ladder.

The drums of the central winch and the rotor are to be driven by an electric motor of the same voltage, of 40 H.P., at 380 revolutions.

A similar electric motor will actuate the ladder winch.

The suction pipe will have a diameter of 600 millimetres, while its length will be such as to permit dredging operations at a depth of 15 metres at an angle of 45 degrees.

Above the sun-protecting roof there are two pilot houses, one containing all the handles for operating the vessel when it is used as a cutter suction dredger, the other containing the handles for operating it as a barge-discharging suction pump.

Also, this vessel is to be equipped with patent rotor spuds, 800 millimetres diameter, and 21 metres in length, the distance between their centre lines being 1·50 metres ; this fixes also the maximum width of the pitch.

On the forecastle near the well there is a simple spud to anchor the vessel, when it is being used as a barge-discharging suction dredger.

Finally, we may draw attention to the fact that when the dredger operates as a cutter the discharge pipe leaves the stern at about water level.

VARIOUS APPLICATIONS

It has been mentioned that bucket dredgers have been frequently used for other than the ordinary dredging purposes ; the same may be said of the suction and force-pump dredgers.

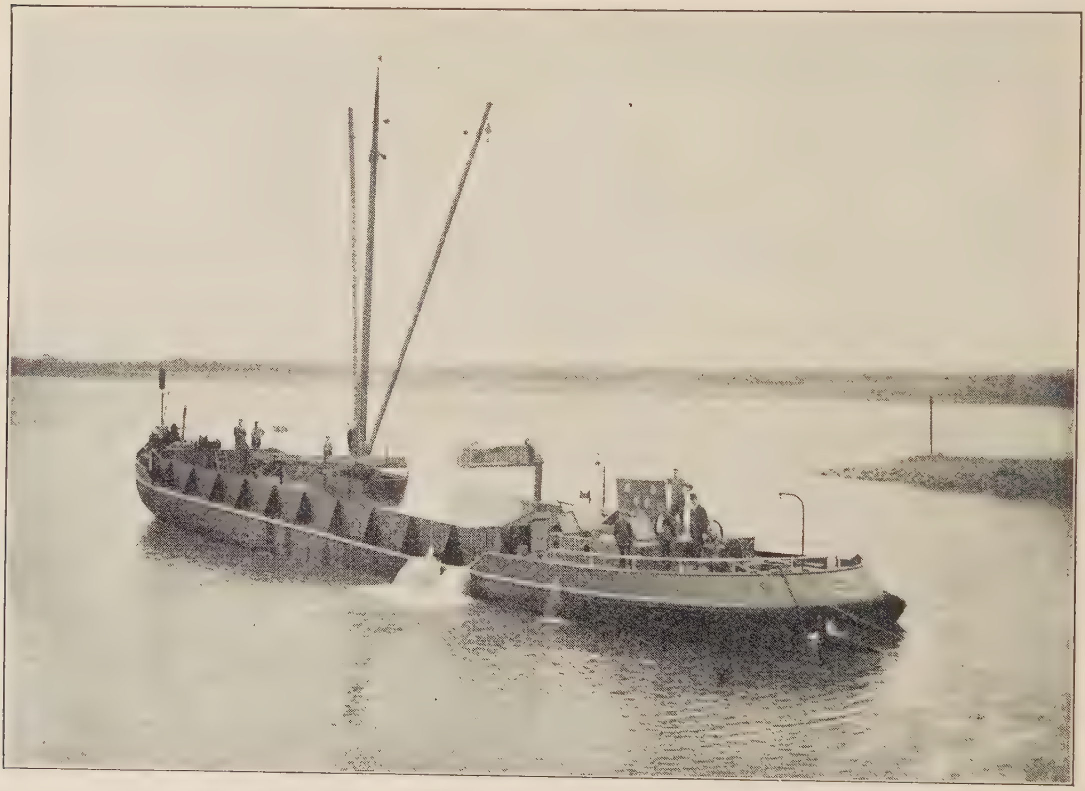


Fig. 136.

As a first application we may mention the " shell suction dredger." It is evident that these vessels operate in places where many shells, mixed with sand on or near the sea-shores, are found.

The dredgings are conveyed to a rotary screen in which the shells remain behind. They are automatically moved towards the end of the screen by means of an archimedian screw, where they are collected, while the sand is conveyed into the sea.

A second application is the gravel suction dredger. Again the material is conveyed to a rotary screen, and the sand allowed to flow back into the sea. The screen has a number of holes of different sizes, so that the gravel is sorted into different sizes before dropping into the various compartments of the hold above which the screen is placed.

A third application is the motor sand-suction dredger (Fig. 136), a decked barge, shaped like a ship, in which a crude oil motor is placed, which can either drive the sand-pump or the propeller. These vessels pump river sand, which is stored on the deck. When they are used at limestone works the delivery end carries a simple sieve or screen, so that sand of the required fineness is deposited on deck, while the superfluous material is conveyed to the river. The loading capacity is usually rather more than 100 cubic metres.

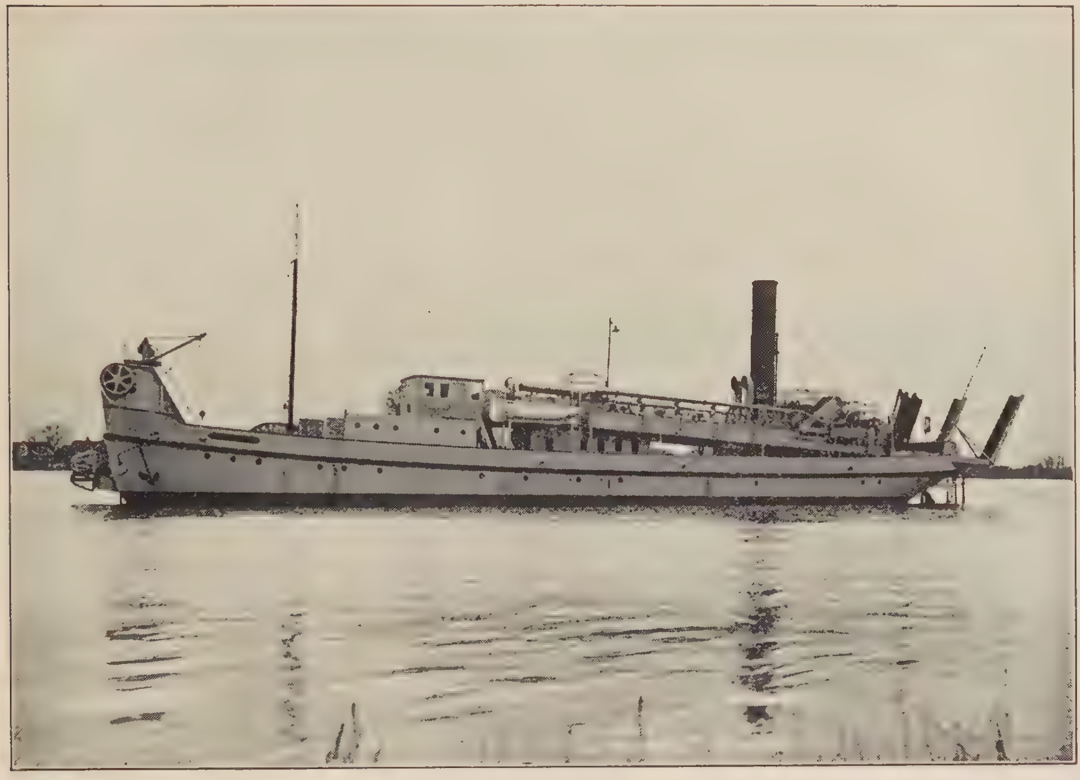


Fig. 137.

An isolated instance is the fibre cutter suction dredger (Fig. 137), built for the Asiatic Fibre Co. This vessel is used in Australia for dredging silted mud which contains roots of seaweed. This fibrous material is used for manufacturing half-woollen fabrics for clothes.

The cut-up and drawn-up spoil is led on both the starboard and port sides into longitudinal shoots, which extend over the stern. The fibres are caught by a rake at the end of the shoots.

The latest application to be mentioned is that of the tin cutter suction dredger (Fig. 135).

This suction dredger conveys the stanniferous cut-up ground, through a discharge pipe to the launders containing transverse partitions. The tin-ore, owing to its greater specific gravity, settles against these partitions, and, just as described with the tin dredgers, it is washed again in the launders, after which it is removed.

Having come to the end of our description of bucket- and suction-dredgers, before we close we might mention that very often appliances are introduced to carry out certain special duties in addition to those for which the vessel was designed. As a rule these can be readily achieved without great expense, as there is usually ample engine and boiler power on the vessels which can be used for all kinds of purposes.

Of such combined appliances the principal are mentioned here, although this does not mean that other combinations are not possible :

(*a*) Bucket dredger, at the same time force-pump dredger.
(*b*) Bucket dredger, at the same time profile-suction dredger.
(*c*) Bucket dredger, at the same time barge-discharging suction dredger.
(*d*) Bucket dredger, at the same time force-pump dredger and profile-suction dredger.
(*e*) Barge-discharging suction dredger, at the same time profile-suction dredger.
(*f*) Barge-discharging suction dredger, at the same time profile-suction dredger and cutter-suction dredger.
(*g*) Hopper-suction dredger, at the same time barge-discharging suction dredger.

It is difficult to say in what direction the further development of dredging appliances will follow. No doubt development will be chiefly influenced by the nature of the work that has to be executed in the future and also. to a much less extent, on the further development and use of crude oil engines.

Improvements are bound to come, improvements which will all aim at reducing the cost of dredging to a minimum. In any case it must be acknowledged that of late years the various dredging appliances have been brought to such a high degree of perfection that they have undoubtedly contributed in no small degree in making it possible to construct the large harbour works and water undertakings as they exist to-day

APPENDICES

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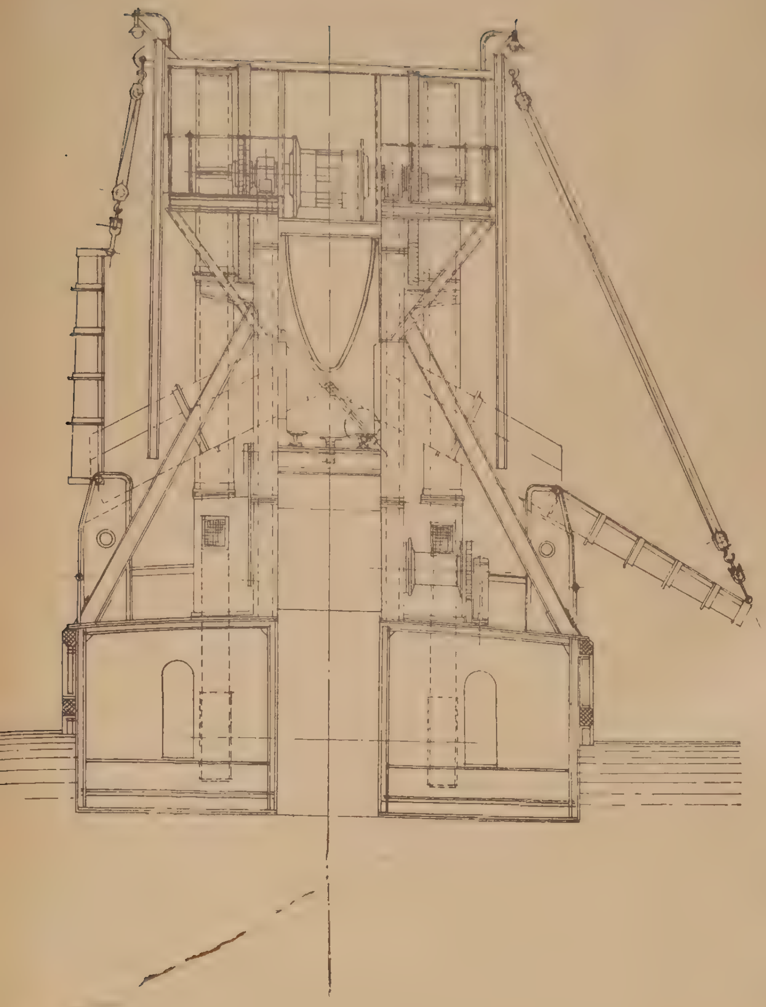
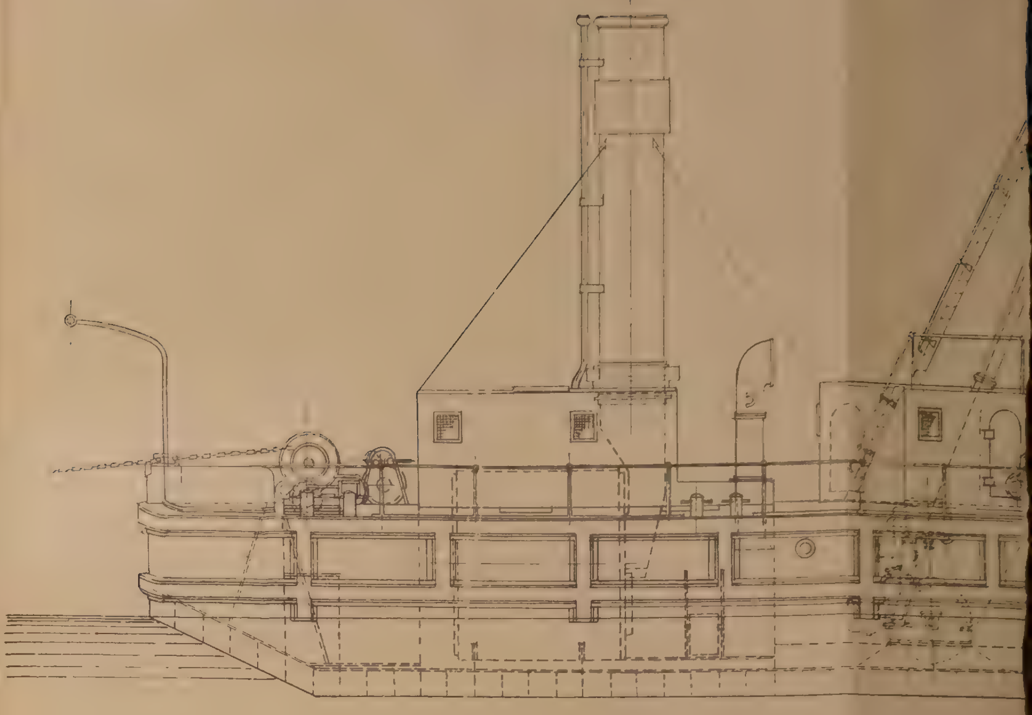
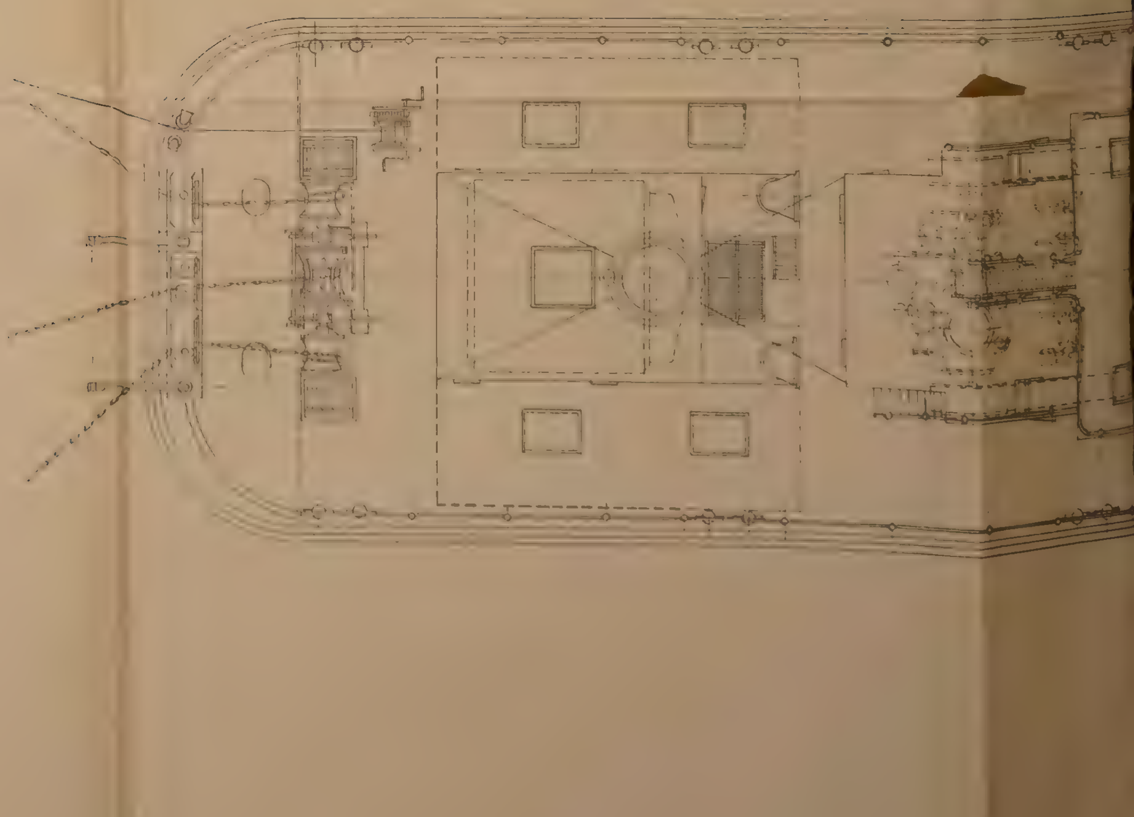
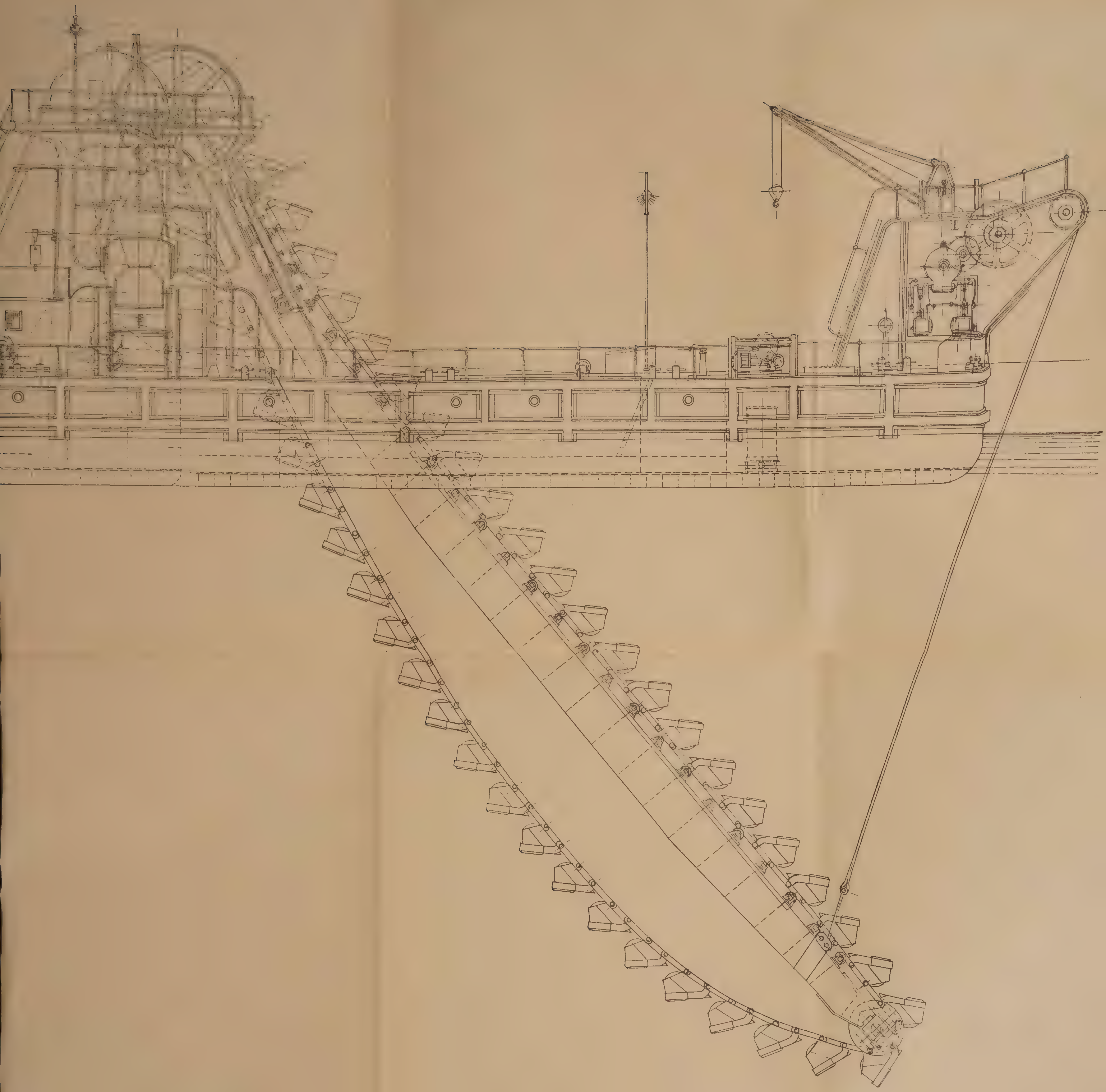
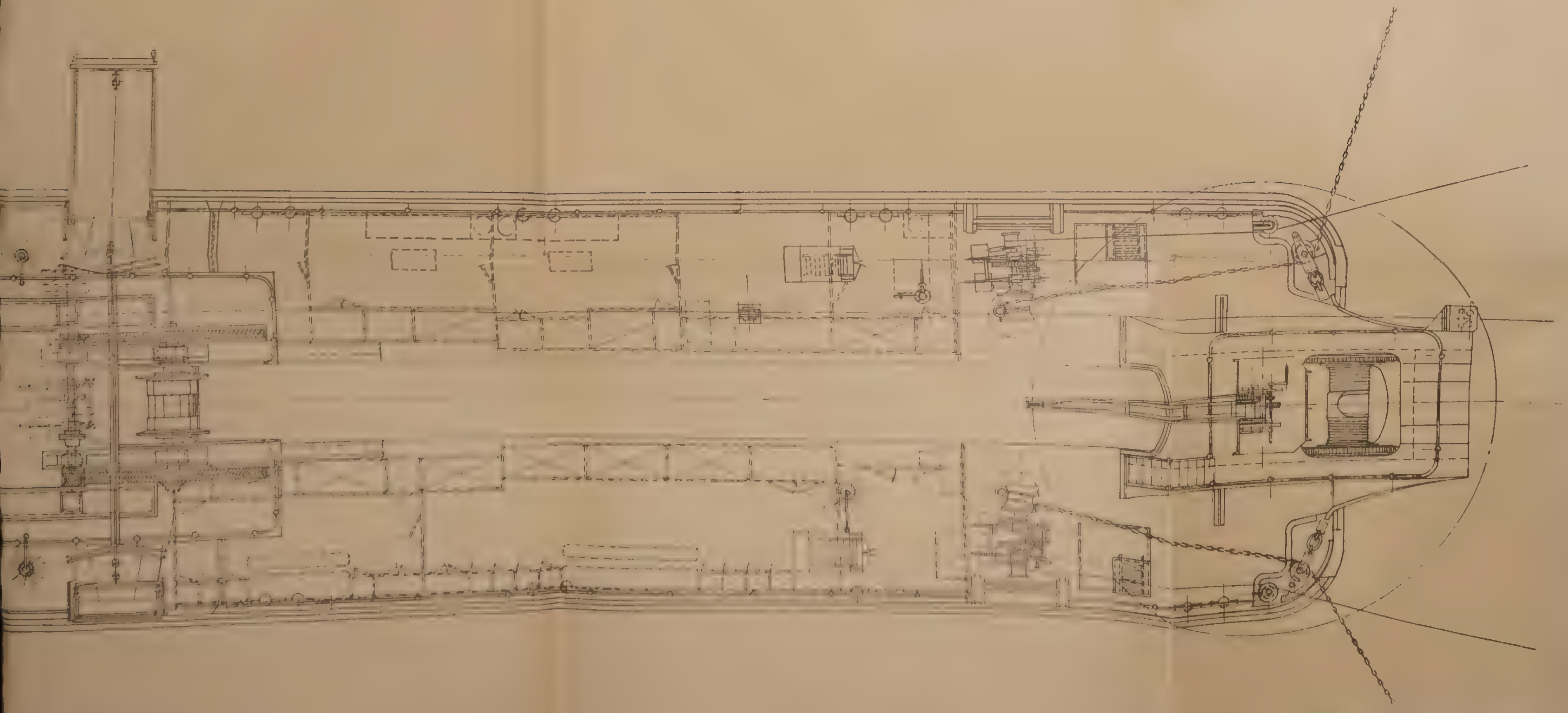


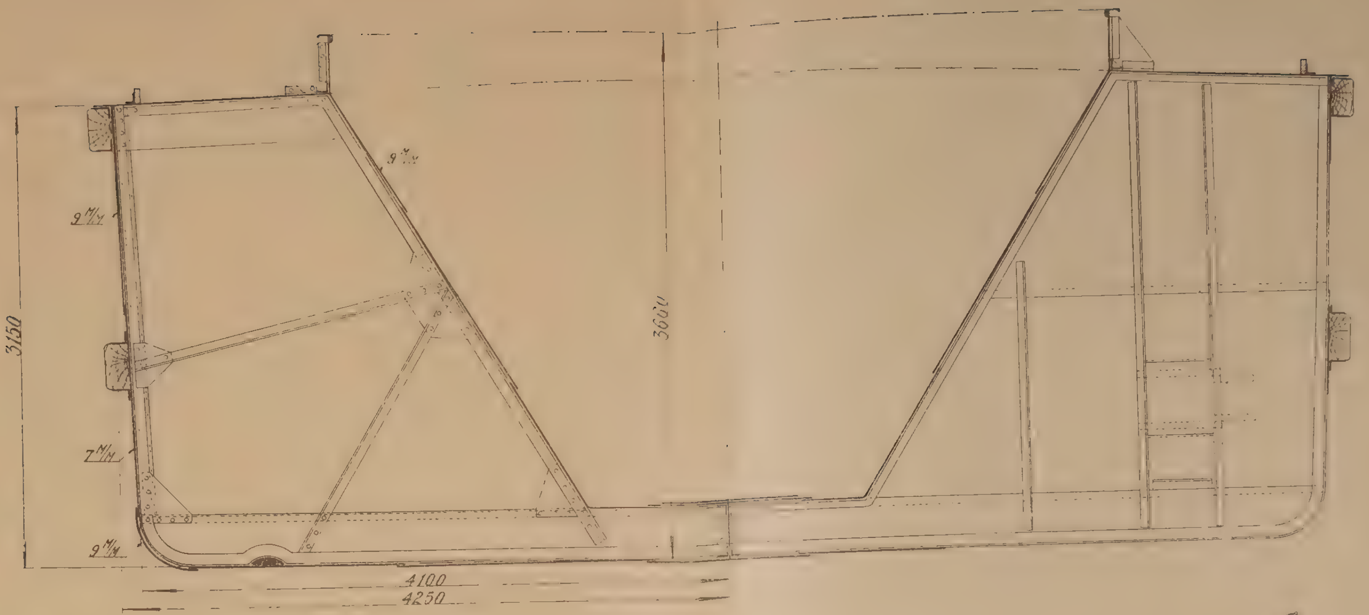


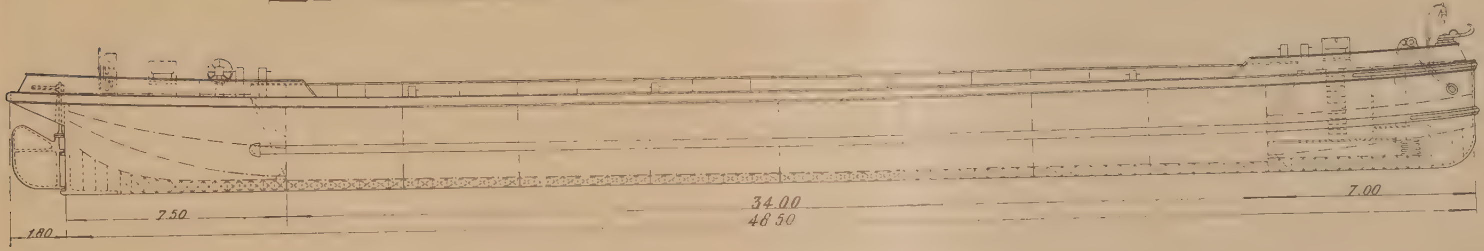


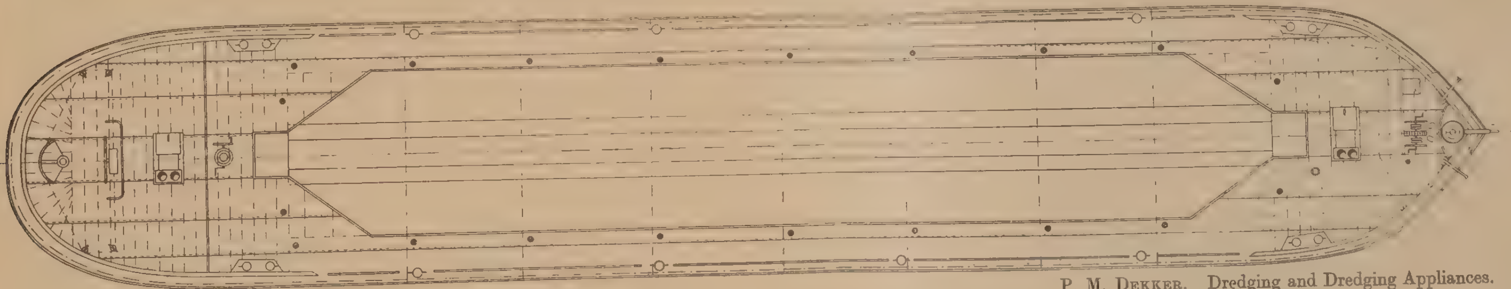




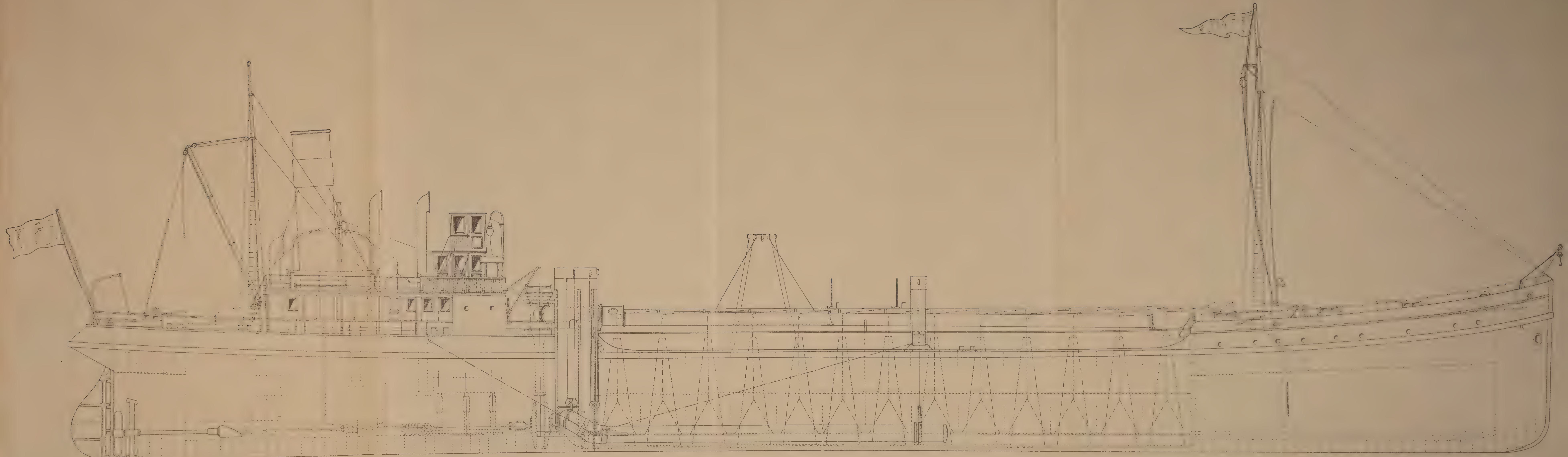
P. M. Dekker. Dredging and Dredging Appliances.
APPENDIX A.







P. M. Dekker. Dredging and Dredging Appliances.
APPENDIX B.



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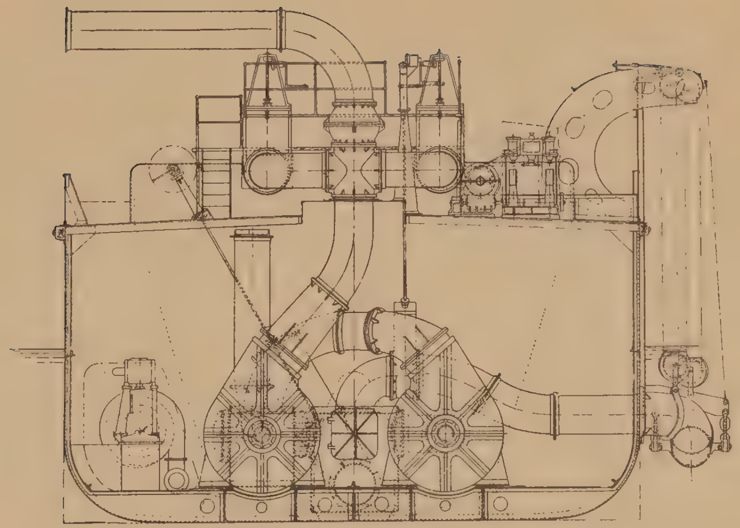
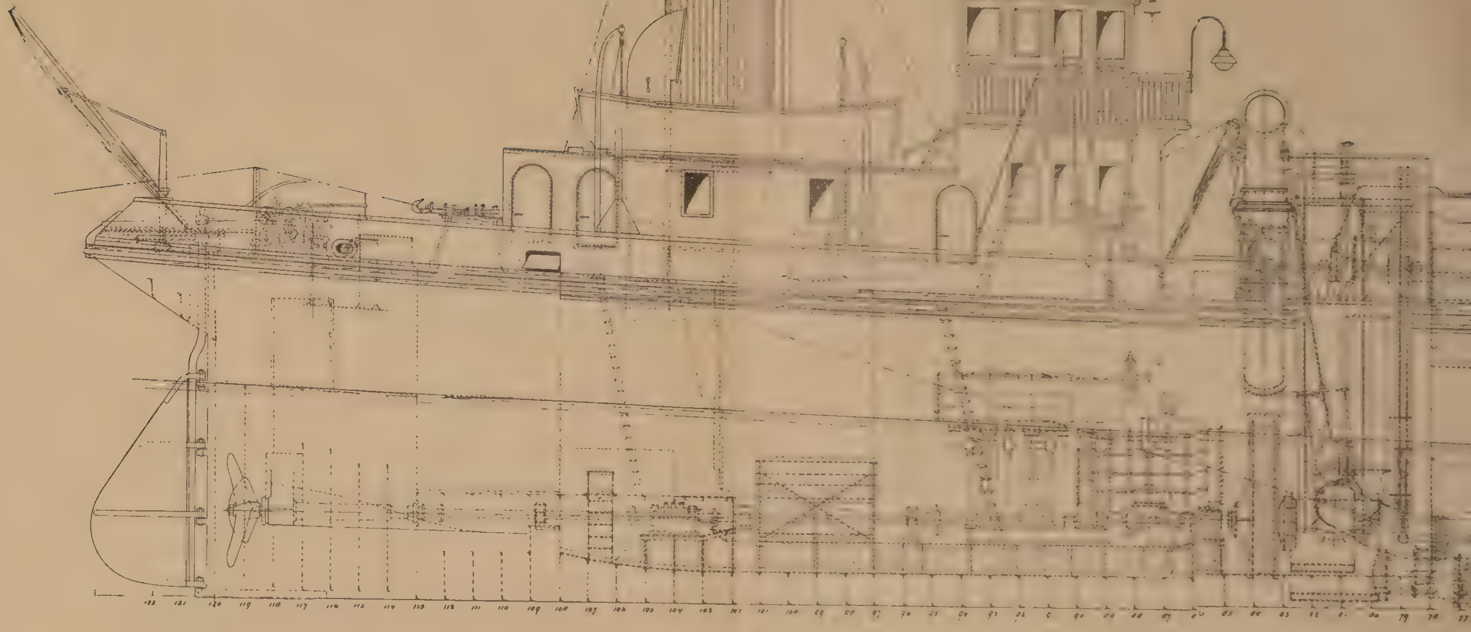
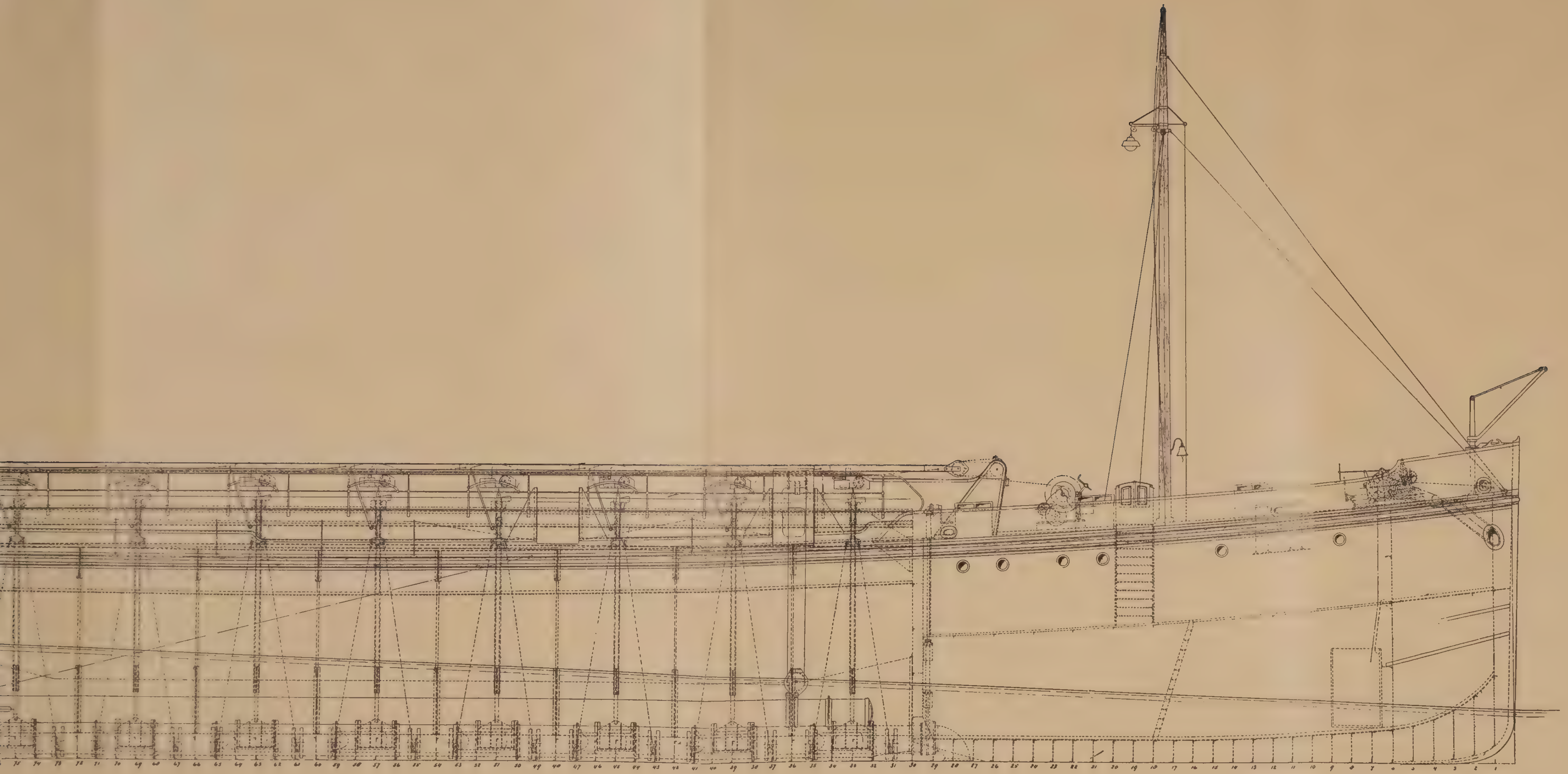
APPENDIX C.







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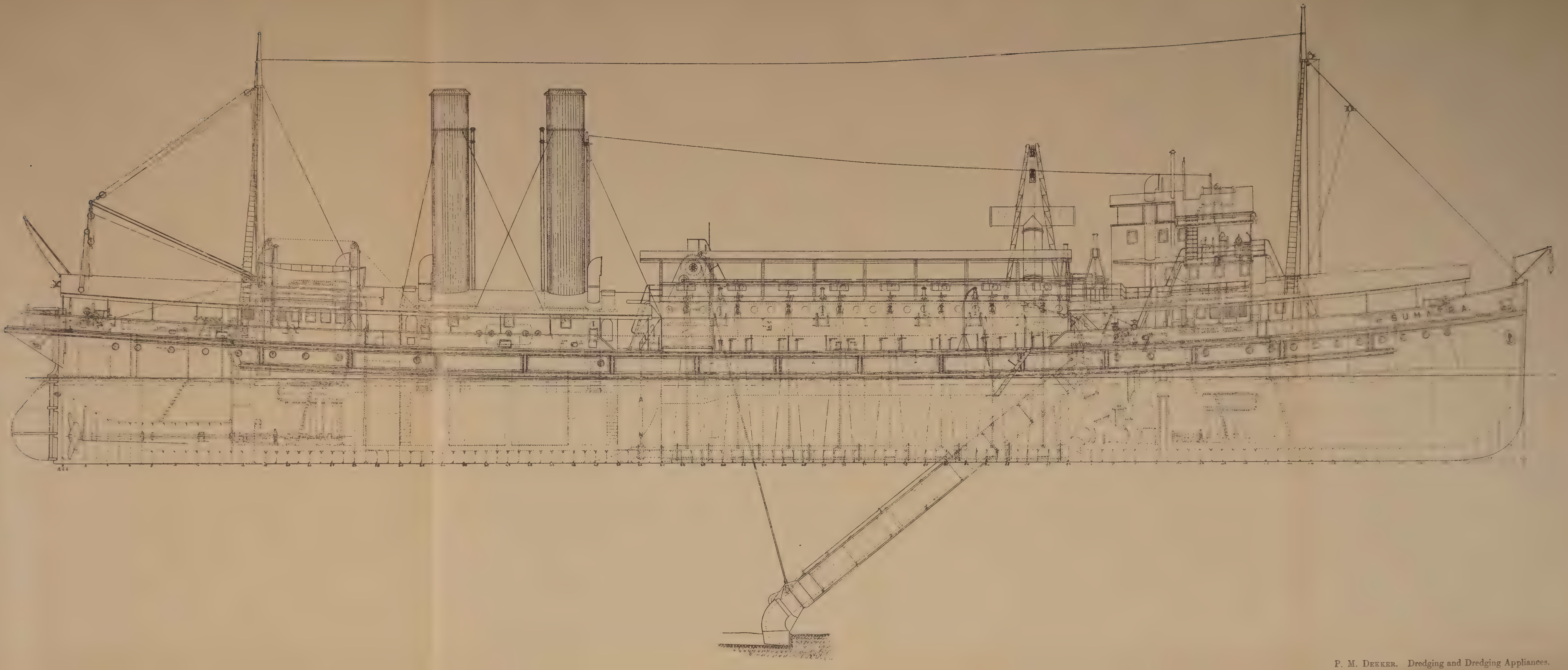
APPENDIX D.



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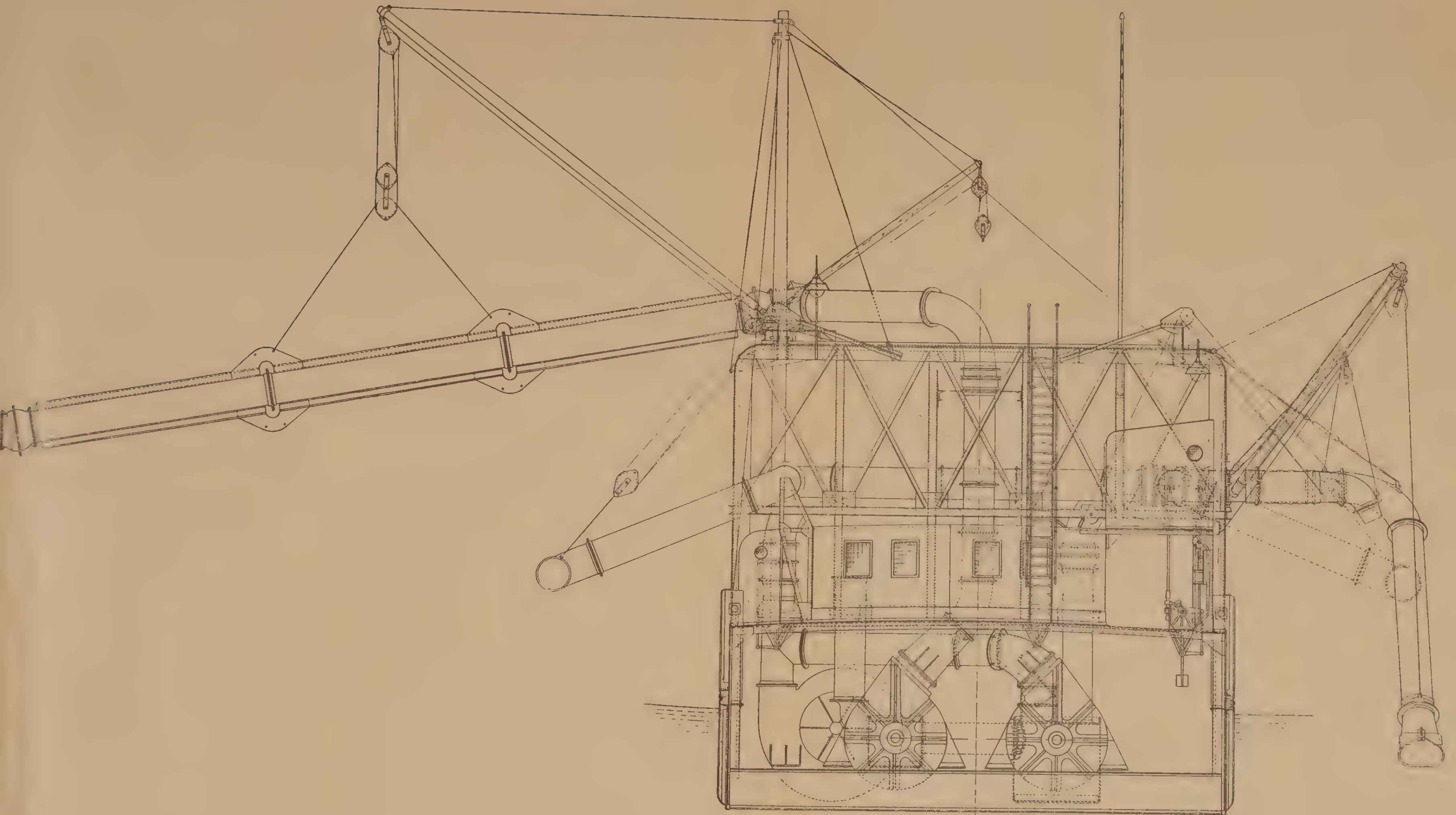
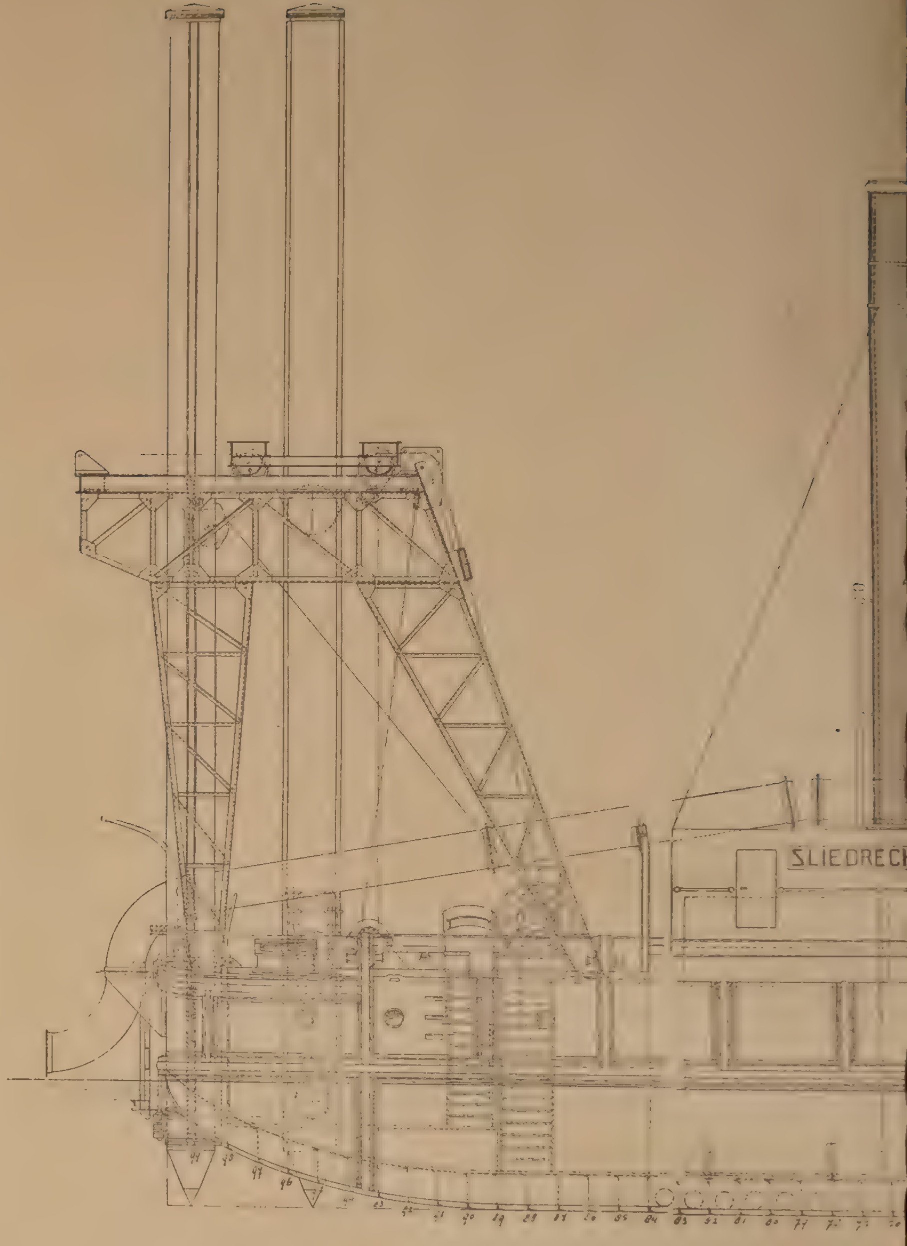
APPENDIX E.

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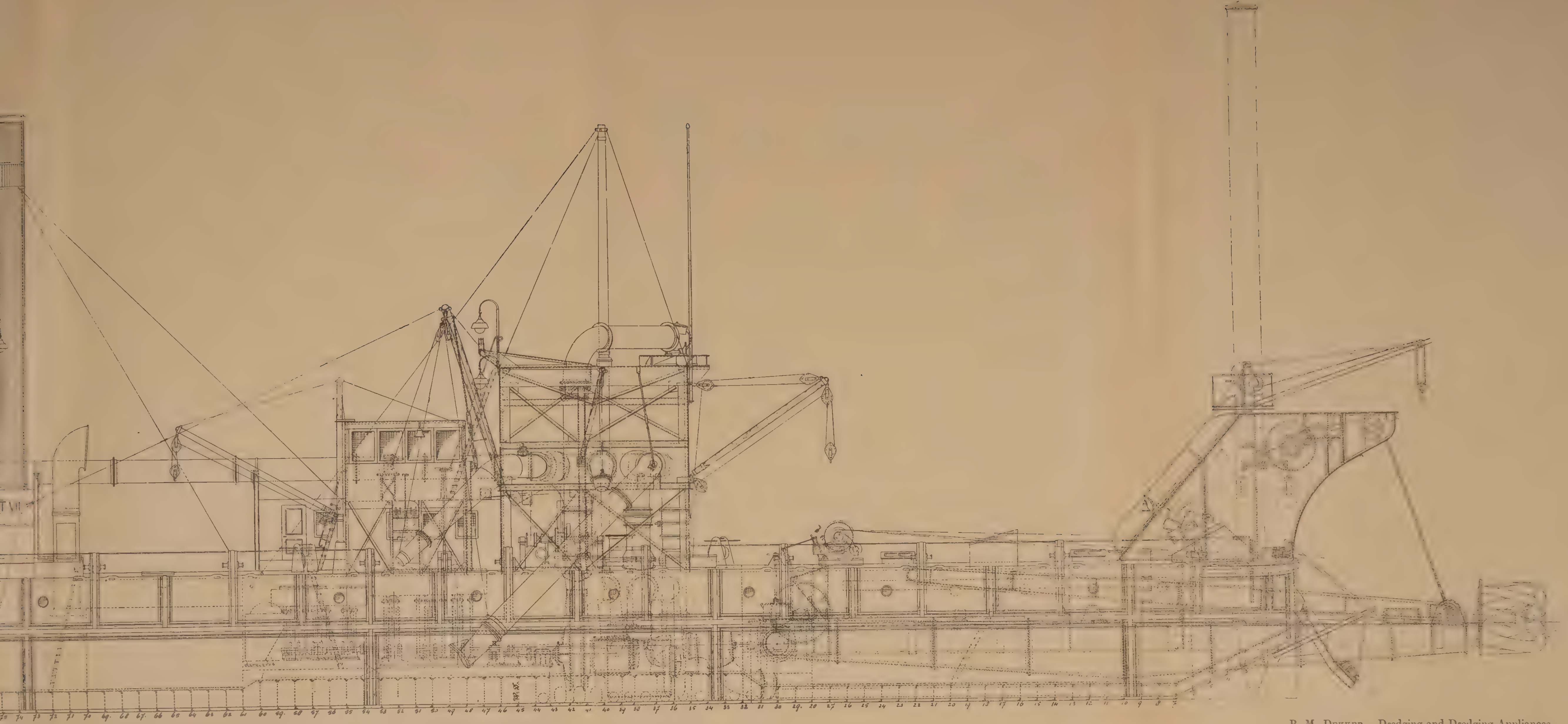

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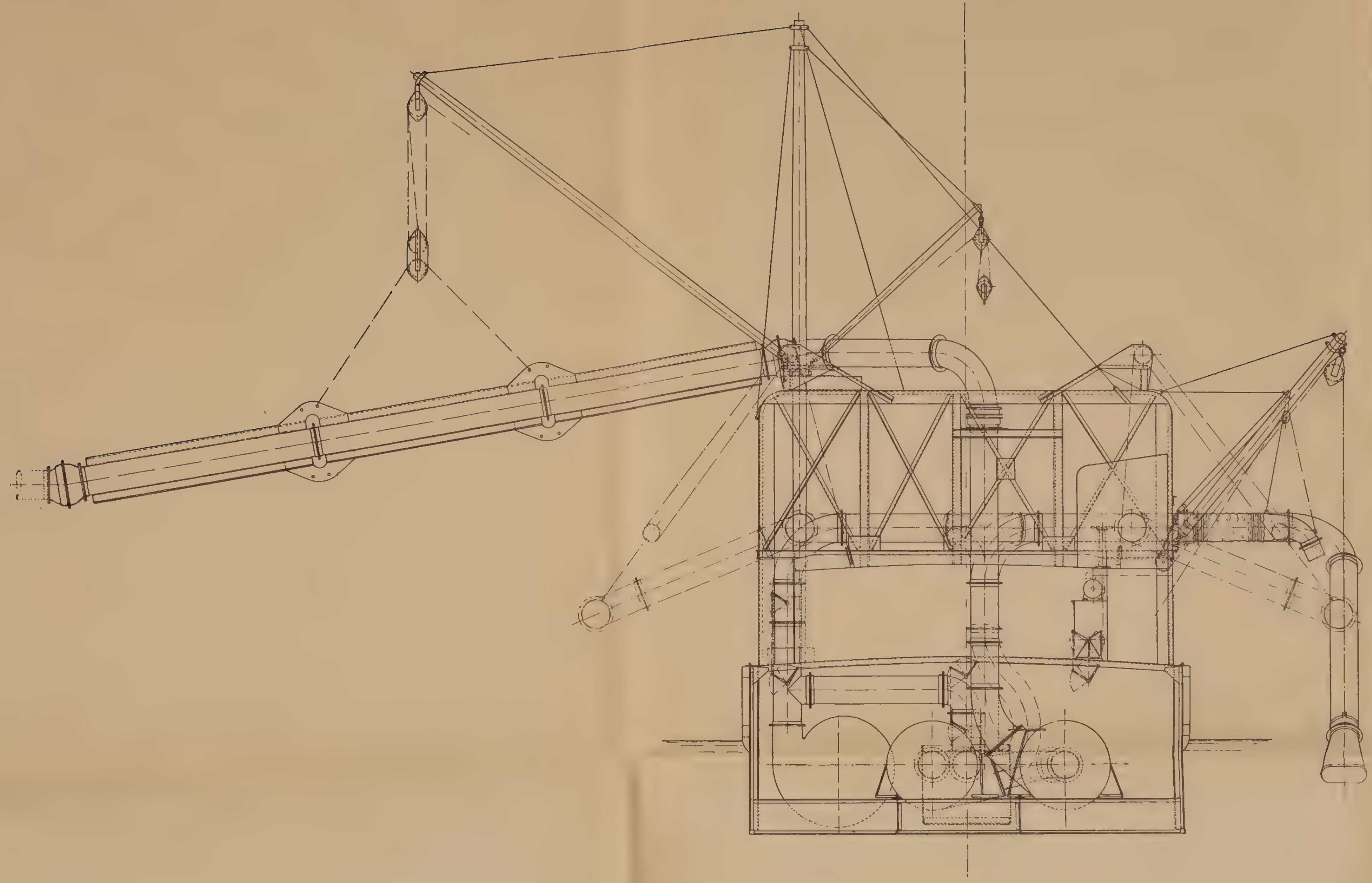
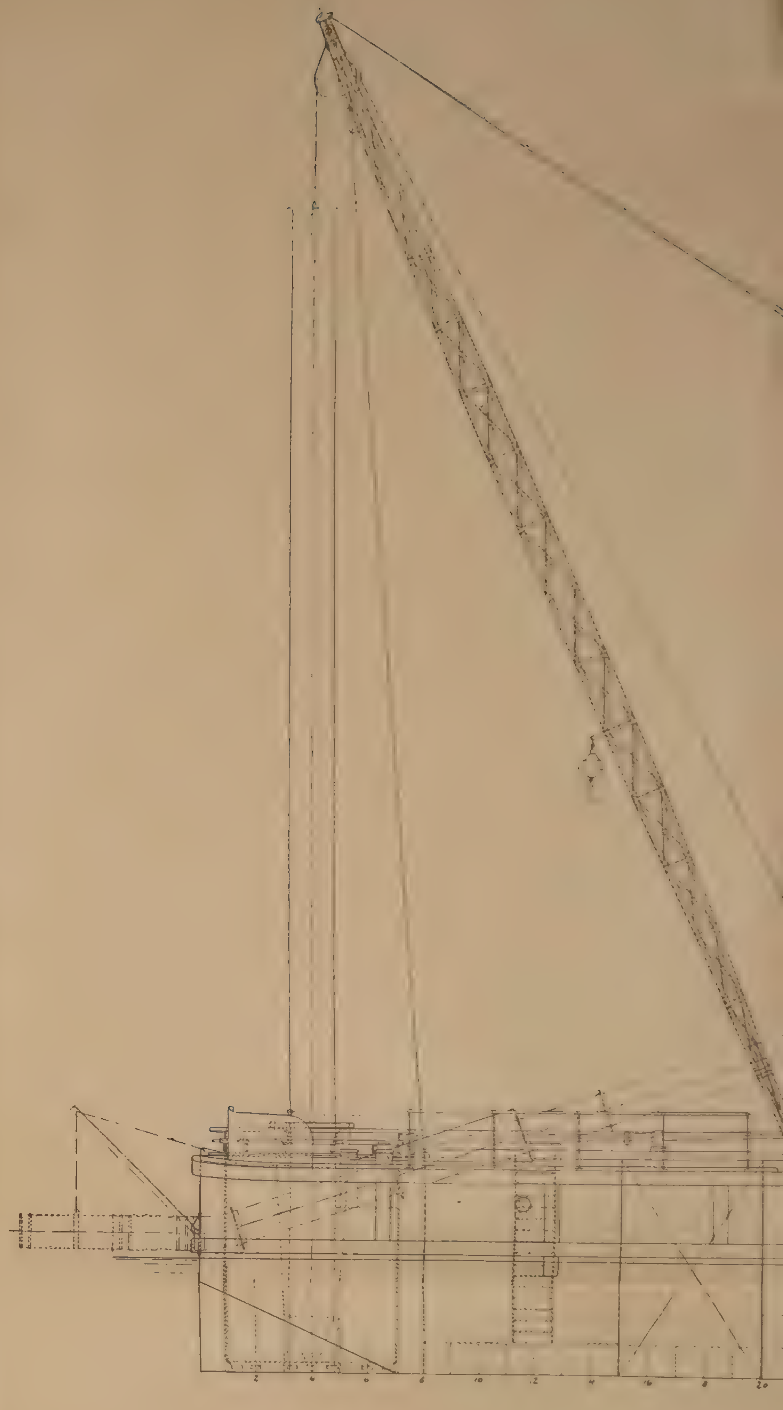
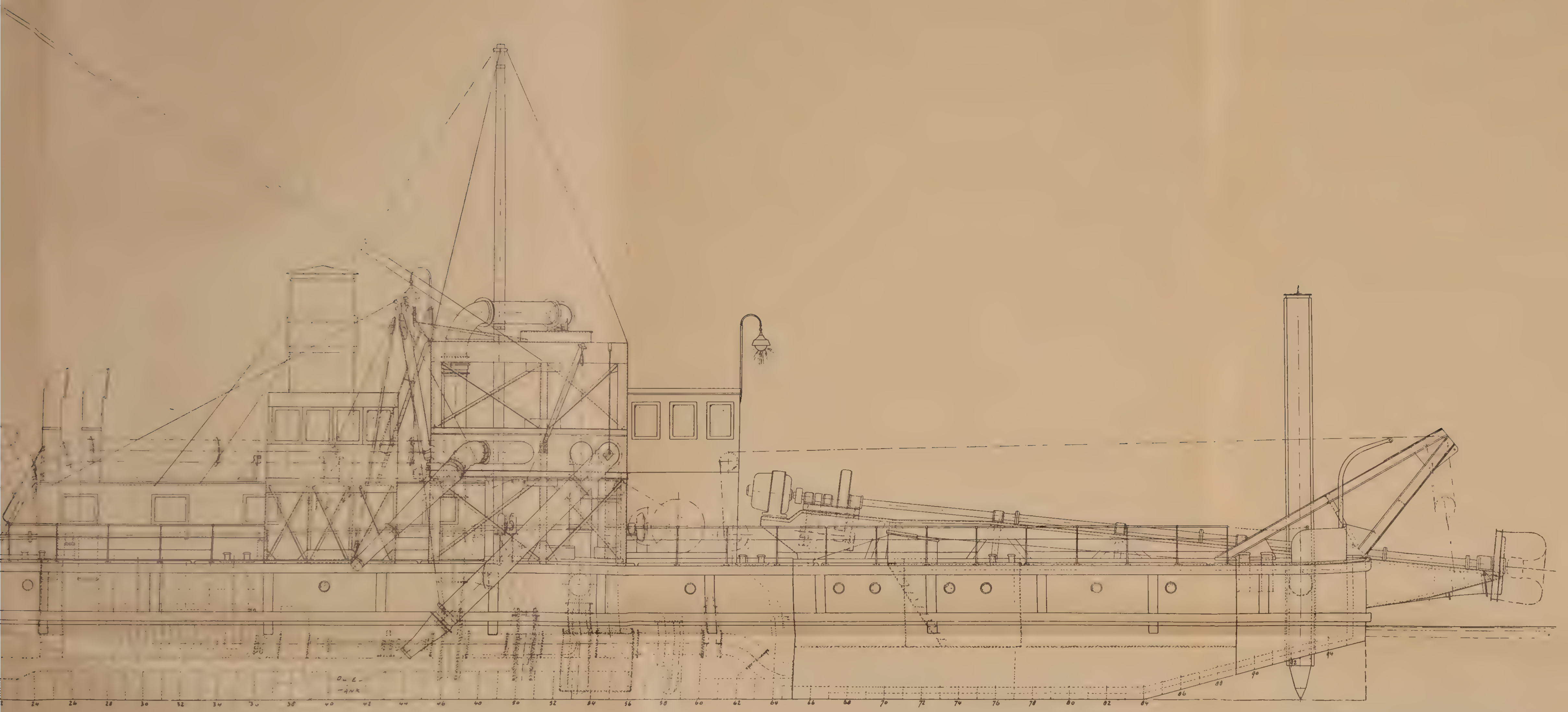
APPENDIX F.







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APPENDIX G.

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